AN ASSESSMENT OF THE STRAYING OF TWO ENHANCED SOCKEYE SALMON STOCKS ON NORTHERN AFOGNAK ISLAND, AS INFLUENCED BY ARTIFICIAL BARRIERS PREVENTING ACCESS TO FRESHWATER

Figure 1 was not recovered for this archived version of 4K00-53

By

Jeff A. Wadle
and
Steven G. Honnold

Regional Information Report[1] No. 4K00-53

Alaska Department of Fish and Game
Division of Commercial Fisheries
211 Mission Road
Kodiak, AK 99615

July 2000

---

[1] The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished division reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Division of Commercial Fisheries.

ACKNOWLEDGMENTS

We acknowledge Alaska Department of Fish and Game personnel Rob Baer, Jesse Campbell, Steve Clevenger, Jim Penkusky, Rob Markle, Wes Ghormley, Oliver Roberts, Steve Thomsen and Elaan Thomas, for compiling data and collecting scale samples. We also acknowledge Ken Bouwens, Dave Prokopowich, Dan Moore and Donn Tracy for editorial comments; Steve Schrof for helping with tables and figures; Nick Sagalkin, and Ivan Vining, for a refresher in statistical analysis; Joanne Brodie for providing weir data and Lucinda Neel for publication expertise.

Funding for these projects were provided by Kodiak Regional Aquaculture Association.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

The ADF&G genetics policy provides guidelines to protect wild stock salmon from genetic intrusion of hatchery-reared salmon. This policy suggests that terminal fisheries, if not properly implemented and monitored, might increase the incidence of straying and possibly compromise the genetic integrity of the nearby wild stock sockeye salmon *Oncorhynchus nerka*. Specifically, if returning enhanced sockeye salmon find the rearing stream blocked by a barrier, the fish would then stray to other streams to spawn.

The Terminal Harvest Areas (THA) in Foul Bay and Waterfall Bay both have artificial barriers used to prevent enhanced sockeye salmon from migrating up stream into freshwater. The ADF&G genetics staff suggested that there is a potential for the enhanced fish to stray into nearby wild sockeye salmon streams. In 1998 and 1999, Thorsheim Creek (near Hidden Creek) and Portage Creek (near Waterfall Creek) were assessed to determine if enhanced sockeye salmon were straying into these wild systems.

The ADF&G research staff proposed that enhanced sockeye salmon would be visually discernable from wild stock sockeye salmon by the unique characteristic seen in scale freshwater growth patterns. The growth rates of enhanced fish and wild fish are substantially different due to feeding patterns and rearing environment.

Scales were collected at both THAs as well as Thorsheim Creek and Portage Creek. The scales were visually scrutinized for straying sockeye by observing the freshwater growth on the scale annulus and circuli. From the results of the stock identification analysis, we believe that it was unlikely there was significant straying of enhanced sockeye salmon into the wild stock sockeye salmon systems from the THAs.

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) began stocking sockeye salmon, *Oncorhyncus nerka*, into barren Hidden and Little Waterfall Lakes in 1992. (White 1992; Edmundson et al. 1994 ADF&G 1999). These projects were implemented to enhance the northern Afognak Island commercial fisheries. Returns to Hidden Lake are harvested in the Foul Bay Terminal Harvest Area (FBTHA) and returns to Little Waterfall Lake are harvested in the Waterfall Bay Terminal Harvest Area (WBTHA; Figure 1). Beginning in 1995, barriers were installed on Hidden Creek (barrier weir) and at the terminus to Little Waterfall Creek (barrier net) in order to prevent returning enhanced sockeye salmon from migrating upstream. These barriers allowed fishermen in the area to catch most of the returning sockeye salmon in Terminal Harvest Areas (THAs; Honnold et al. 1998). When a harvestable surplus of enhanced sockeye salmon was documented in the THAs, continuous fishing periods were announced by ADF&G (beginning 09 June; Honnold et al. 1999).

The ADF&G genetics policy provides guidelines to protect wild stock salmon from genetic intrusion of hatchery-reared salmon (McGee 1995). This policy suggests that if returning enhanced sockeye salmon find their natal stream blocked by a barrier, the fish would then stray to other streams to spawn and possibly compromise the genetic integrity of the nearby wild stock sockeye salmon. Some of the potential impacts of enhanced stock gene flow into a natural stock population include: introduction of deleterious alleles, loss of adaptive genetic variation, loss of reproductive success, outbreeding depression, and displacement of wild fish (Quinn 1993; Grant 1997; Unwin and Glova 1997). Thus, the use of barriers to improve the harvest of enhanced returns to the THAs was not considered compliant with the ADF&G policy. Consequently, permits for stocking Hidden and Little Waterfall Lakes were reissued in 1997 with a stipulation that straying rates at Thorsheim Lake, which is near the FBTHA, and Portage Lake, which is near the WBTHA, would be assessed (Honnold et al. 1998).

The ADF&G proposed that enhanced sockeye salmon would be visually discernable from wild stock sockeye salmon by the unique characteristic seen in scale freshwater growth patterns (Nelson and Barrett 1994; Honnold et al. 1998). The juvenile growth rates of enhanced fish and wild fish are substantially different due to feeding patterns and rearing environment. Enhanced fish are fed and reared as juveniles in hatchery raceways and grow rapidly (Honnold et al. 1999). Wild juveniles usually grow at much slower rates. The natural stocks at the Thorsheim and Portage Lake systems have historically exhibited tight circuli patterns along with overall smaller freshwater scale growth. The Hidden Lake and Little Waterfall Lake enhanced stocks show large freshwater circuli patterns and greater freshwater scale growth. The differences in freshwater scale growth make it generally possible to differentiate enhanced sockeye salmon from wild sockeye salmon.

Another method of stock identification is through Scale Pattern Analysis (SPA) using a linear discriminate function analysis (Nelson 1999). However, the basic parameters needed for the test are not met; this procedure of stock identification requires the use of at least two “known” populations along with the “unknown” population to be differentiated. The SPA was not used to differentiate stocks.

Purpose of Report

The purpose of this report is to describe the methods used to detect straying sockeye at Thorsheim and Portage Creek and to assess the proportion of straying enhanced stock sockeye salmon found in the wild stock systems.

Description of the Study Areas

Hidden Lake (58° 23’ N, 152° 42’ W) is located on the northwest side of Afognak Island, ~ 70 km northwest of the city of Kodiak (Figure 1). The outlet stream of the lake is ~ 2.4 km long and empties into Foul Bay. The first barrier fall that is impassable to sockeye salmon is located ~ 1 km upstream from salt water.

Little Waterfall Lake (58° 22’ N, 152° 33’ W) is located on the north end of Afognak Island, ~ 65 km north of the city of Kodiak (Figure 1). The outlet stream of the lake is ~ 3.5 km long and drains into Little Waterfall Bay. The barrier fall impassable to sockeye salmon is located ~ 0.8 km upstream from saltwater.

Portage Lake (58° 16’ N, 152° 25’ W) is located on the north end of Afognak Island, ~ 60 km north of the city of Kodiak (Figure 1). The outlet stream of the lake is ~ 1.6 km long and drains into Discoverer Bay.

Thorsheim Lake (58° 15’ N, 152° 49’ W) is located on the northwest side of Afognak Island, ~ 60 km northwest of the city of Kodiak (Figure 1). The outlet stream of the lake is ~ 1.6 km long and empties into Paramanof Bay.

METHODS

Data Collection

Escapement Enumeration

Thorsheim Lake (Creek) sockeye salmon, for both the 1998 and 1999 field seasons, were enumerated using a weir (ADF&G 1998; ADF&G 1999). In 1998, the weir was installed on 29 May and removed on 29 June. In 1999, the weir was installed on 29 May and removed on 27 June. After the removal of the weir in 1998 and 1999, post-weir estimates were obtained. Visual assessments were used to estimate the number of sockeye salmon remaining in the bay.

The 1998 and 1999 Portage Lake (Creek) system sockeye salmon escapement numbers were estimated using peak escapement counts (R. Baer, Alaska Department of Fish and Game, Kodiak, personal communication). The escapement counts were obtained by foot surveys on the various tributaries draining into Portage Lake. The total escapement was then estimated by multiplying the subsequent counts by a correction factor of two (Barrett et al. 1990).

THA Harvest

The 1998 and 1999 FBTHA and WBTHA sockeye salmon harvest numbers were obtained from the ADF&G fish ticket data base.

Sample Sizes

Sample sizes were estimated using SamplePower (Borenstein 1997). The program uses a normal approximation to estimate sample sizes assuming a binomial distribution with a specific proportion. In this case the proportion used was 0.02.

Escapement/Catch Sampling and Age Designation

In 1998 and 1999, sockeye salmon scale samples were collected at the FBTHA and WBTHA from the commercial harvest. Catch sampling occurred weekly with a targeted sampling size of 150 scales per week for a total of 600 scales. Specific collection methods can be found in ADF&G (1999).

Scale collection at Thorsheim Creek took place weekly with a goal of 280 scale samples per week. Trapping and sampling methods were performed as described in ADF&G (1999).

The target sample size for the Portage Lake system was 600 fish. The fish were collected using a beach seine. Collection and sampling methods were performed as described in ADF&G (1999).

Scales were removed from the preferred area of the fish as outlined in INPFC (1963). Scales were mounted on gum cards and impressions were made on cellulose acetate (Clutter and Whitesel 1956). Methods utilized for age designation followed rules outlined in Koo (1962). Age designation followed the European notation where a decimal separates the freshwater age from the saltwater age. Ages were classified using a microfiche reader (48x).

Data Analysis

Stock Identification

The scales sampled at the study areas were classified as either natural or enhanced stock sockeye salmon using a microfiche projector (48x). In order to identify scales from a hatchery fish, it was necessary to establish known scale patterns and provide standards to which to refer when looking for enhanced fish within the natural systems. Standards were selected from the FBTHA and WBTHA catch samples collected in 1998 and 1999. The first selection process was to examine all catch sample scales and select enhanced fish scales. The freshwater growth patterns of the enhanced stock show considerably more growth than the wild fish in the area. The differential growth rates made it relatively easy to select enhanced fish from the sample.

The next process involved comparing previously collected presmolt scales to the adult scales. Presmolt scales had been collected prior to the release of the presmolt into Hidden and Waterfall Lakes. The presmolt scales selected for examination were from presmolt released in 1994, which returned as age 1.3 fish in 1998, and pre-smolt released in 1996, which returned as age 1.2 fish in

1999. By using the appropriate presmolt scale samples for reference (Appendices A.1 – A.4), it was possible to look at the FBTHA and WBTHA scales patterns and substantiate the determination of an enhanced fish scale. Photographs of adult sockeye scales were taken and subsequently used as standards.

The scales shown in the Appendices B.1 – B.6 and C.1 – C.6 are examples representing the differences within age classes between the populations. Freshwater age 1 fish were used in the analysis because it was the predominant freshwater age (~90%) of the enhanced stock sockeye salmon returning to FBTHA and WBTHA. The comparison of age 1.3 fish in 1998 between Thorsheim Lake/FBTHA and Portage Lake/WBTHA was selected because that age class had the greatest number of comparable scales; other age classes did not have a significant representation for both areas (Table 1). The same was true with the 1999 comparison of age 1.2 fish (Table 2).

Another method used to differentiate enhanced fish from natural fish was to measure the circuli and annulus of the scale. The scales were measured using a digitizing camera to identify freshwater scale growth patterns. The unit of measurement was classified as a “unit”. This was a relative measurement that can be converted to micrometers. The “unit” designation was sufficient to describe the differences in scale growth between the enhanced salmon and wild salmon.

Two measurements were applicable to this method. One was the freshwater growth from the focus of the scale to the outside circuli of the first annulus, providing a total growth measurement. The second measurement was the number of circuli from the focus to the first annulus but not including scale growth after the outside circuli of the first annulus, which omits post winter growth for the year smolt migrate from the lake.

Monte Carlo Simulation

Because the desired sample sizes were not collected from Thorsheim Creek (1,120 scales) and Portage Creek (600 scales), a Monte Carlo simulation (Mooney 1997) was used to estimate the probability of sampling zero strayed fish given the sample size.

With an estimate of the total population (N; Table 3) we could simulate a random sampling event. The simulated population was denoted as a column of numbers: ones represented wild fish and twos represented strayed enhanced fish. A total of 2% strayed enhanced fish were placed within the population. The 2% straying rate was the suggested highest acceptable straying rate within a natural population (J. Seeb, Alaska Department of Fish and Game, Anchorage, personal communication). The number of random samples taken from the simulated population (n) was the same as the number of ageable scales taken in the field. The simulation was run 1000 times. The strayed fish sampled were then counted from each simulated sample and plotted on a frequency distribution graph.

RESULTS

Data Collection

Escapement Estimates

A total of 1,248 adult sockeye salmon were passed through the Thorsheim Creek weir in 1998 (Table 4). The season total escapement included a post-weir estimate of 5,000 sockeye salmon. This estimate brought the estimated total escapement to 6,248 adult sockeye salmon. In 1999, a total of 4,978 adult sockeye salmon were passed through the Thorsheim weir with a post-weir estimate of 1,000. This estimate brought the total estimated escapement to 5,978 fish.

In 1998, a total of 1,974 live sockeye salmon were counted within the tributaries draining into Portage Lake (Table 5). The correction factor brought the total escapement estimate to 3,948 fish. In 1999, a total of 2,951 live sockeye salmon were counted within the tributaries draining into Portage Lake. The correction factor brought the total escapement estimate to 5,902 fish.

THA Harvest

In 1998, a total of 8,270 sockeye salmon were caught during the FBTHA fishery (Table 6). In 1999, a total of 27,302 fish were caught in the fishery.

In 1998, a total of 11,057 sockeye salmon were caught during WBTHA fishery (Table 6). In 1999, a total of 9,359 fish were caught in the fishery.

Sample Sizes

The required sample size for Thorsheim Creek equaled 1200 sockeye salmon scales. The required sample size for Portage Creek equaled 600 sockeye salmon scales.

Escapement/Catch Sampling and Age Designation

In 1998, a total of 684 adult sockeye salmon were sampled from the Thorsheim Creek escapement for age, length and sex; the number of ageable scales was 519 (Table 1). The primary age classes for the sampled sockeye salmon were age 2.2 (44%) and 1.3 (37%) fish. In 1999, a total of 452 adult sockeye salmon were sampled at the Thorsheim weir. The number of ageable scales equaled 419 (Table 2). The primary age classes for the sampled sockeye salmon were age 2.3 (64%) and age 1.2 (27%) fish.

In 1998, a total of 407 adult sockeye salmon were sampled from the Portage Lake escapement for age, length and sex; the number of ageable scales was 283 (Table 1). The primary age classes were age 2.1 (33%), and age 2.2 (29%) fish. In 1999, a total of 621 adult sockeye salmon were sampled at Portage Lake. The number of ageable scales equaled 510 (Table 2). The primary age classes were age 1.2 (50%), age 2.3 (18%) fish and ages 1.3 and 2.2 fish, both at 15%.

There were 803 sockeye salmon sampled for age, length and sex data in the 1998 FBTHA fishery. The number of ageable scales was 646 (Table 1), with the primary age classes being 1.2

(51%), 1.1 (25%), and 1.3 (15%) fish. In the 1999 FBTHA fishery, there were 810 adult sockeye salmon sampled for age, length and sex; the number of ageable scales was 603 (Table 2). The primary age class of the ageable scales was age 1.2 (89%) fish.

During the 1998 WBTHA fishery, 696 sockeye salmon were sampled for age and length data. The number of ageable scales was 491 with the primary age classes being 1.2 (55%) and 1.3 (31%) fish (Table 1). In the 1999 WBTHA fishery, a total of 440 adult sockeye salmon were sampled for age, length and sex; the number of ageable scales was 337 (Table 2). The primary age class of the ageable sample was age 1.2 (78%) fish.

Data Analysis

Stock Identification: Thorsheim Creek and FBTHA Sockeye Salmon

Visual examination of the 1998 and 1999 Thorsheim Creek escapement samples revealed no patterns that are typical of scale patterns from an enhanced fish. A t-test was performed on circuli counts and annulus measurements to test for a difference between the means. All p values were significantly less than 0.0001. Visual differences in the fresh water growth patterns are shown in Appendices B.1 – B.6.

There was a significant difference between the circuli counts of Thorsheim Creek (n = 184) and FBTHA (n = 69) samples in 1998. The total circuli counts of Thorsheim Creek age 1.3 sockeye salmon averaged ~ 11 circuli within the freshwater growth phase while the FBTHA age 1.3 enhanced fish averaged ~ 23 circuli (Figure 2a). The freshwater circuli count and total freshwater growth, plotted on a frequency distribution graph, indicated normal distributions and divergent populations. The two stocks have little or no measured overlap (Figure 2a).

There was a significant difference between the circuli counts of Thorsheim Creek (n = 102) and FBTHA (n = 100) samples in 1999. The total circuli count of Thorsheim Creek age 1.2 sockeye salmon averaged ~ 10 circuli within the freshwater growth phase while the FBTHA age 1.2 enhanced fish averaged ~ 20 circuli (Figure 2b). The freshwater circuli count and total freshwater growth, plotted on a frequency distribution graph, indicated normal distributions and divergent populations. The two stocks have little or no measured overlap (Figure 2b).

There was a significant difference between the annulus growth at Thorsheim Creek (n = 184) and FBTHA (n = 69) samples in 1998. For age 1.3 Thorsheim Creek sockeye salmon, the average growth was 164.37 units while the FBTHA age 1.3 sockeye salmon averaged 289.65 units (Figure 3a). The freshwater circuli count and total freshwater growth, plotted on a frequency distribution graph, indicates normal distributions and divergent populations. The measurements showed that the two stocks had little or no overlap (Figure 3a).

There was a significant difference between the annulus growth at Thorsheim Creek (n = 102) and FBTHA (n = 100) samples in 1999. The average growth of age 1.2 Thorsheim Creek sockeye salmon was 157.99 units while the average growth of FBTHA age 1.2 sockeye salmon was 297.67 units (Figure 3b). The freshwater circuli count and total freshwater growth, plotted on a frequency distribution graph, indicates normal distributions and divergent populations. The measurements show that the two stocks had little or no overlap on the (Figure 3b).

Thorsheim Creek Monte Carlo Simulation

Using the Monte Carlo simulation, it was discovered that given the sample sizes taken at the Thorsheim system (1998 and 1999), there was a 100% probability of detecting at least one strayed fish from the population with a 2% straying rate (Figure 4). The 1998 population size did not include the post-weir estimation of 5,000 sockeye salmon because there were zero fish sampled from the estimate. The 1,000 fish post-weir estimate for the 1999 season was used because some sockeye salmon may have been sampled in the lake beach seine.

Stock Identification: Portage Creek and WBTHA Sockeye Salmon

Visual examination of the 1998 and 1999 Portage Creek escapement samples revealed no patterns that are typical of scale patterns from an enhanced fish. Visual differences in the fresh water growth pattern are shown in Appendices C.1 – C.6.

There was a significant difference between the circuli counts at Portage Creek (n = 45) and WBTHA (n = 100) samples in 1998. The scale measurements indicate separation between the two stocks (Figure 5a). The total circuli count of Portage Creek age 1.3 sockeye salmon averaged ~ 9 circuli within the freshwater growth phase while the WBTHA age 1.3 enhanced fish averaged ~ 18 circuli. The freshwater circuli count and total freshwater growth, plotted on a frequency distribution graph, indicated normal distributions and divergent populations. The two stocks had little or no overlap on the measurements (Figure 5a).

There was a significant difference between the circuli counts at Portage Creek (n = 100) and WBTHA (n = 100) samples in 1999. The total circuli count of Portage Creek age 1.2 sockeye salmon averaged ~ 12 circuli within the freshwater growth phase compared to the WBTHA age 1.3 enhanced fish which averaged ~ 17 circuli (Figure 5b). The plots of the two sets of data on a frequency distribution graph show a possible bimodal population and an overlap of ~ 14.5% of the data points (Figure 5b). Approximately 85% of the population was not overlapping and we are confident they were classified correctly as enhanced fish or wild fish.

There was a significant difference between the annulus growth at Portage Creek (n = 45) and WBTHA (n = 100) samples in 1998. For age 1.3 Portage Creek sockeye salmon, the average growth was ~ 121.02 units while the average growth of WBTHA age 1.3 sockeye salmon was ~ 289.65 units (Figure 6a). The freshwater circuli count and total freshwater growth, plotted on a frequency distribution graph, indicated normal distributions and divergent populations. The two stocks had little or no overlap on the measurements (Figure 6a).

There was a significant difference between the annulus growth at Portage Creek (n = 100) and WBTHA (n = 100) samples in 1999. The age 1.2 Portage Creek (1999) sockeye salmon the average growth was 156.24 units while the WBTHA age 1.2 sockeye salmon averaged 233.39 units (Figure 6b). The plots of the two sets of data showed a possible bimodal population and an overlap of ~ 14.5 percent of the data points (Figure 6b). Approximately 85% of the population was not overlapping and we are confident they were classified correctly as enhanced fish or wild fish.

Portage Creek Monte Carlo Simulation

The Monte Carlo simulation for the Portage Creek run of 1998 resulted in a 0.3% chance of detecting zero strays with a 2% straying rate (Figure 7a). The simulation for the Portage Creek run of 1999 resulted in a 100% probability of detecting at least one strayed fish (Figure 7b).

DISCUSSION

From the results of the stock identification analysis, it appears unlikely that there was significant straying of enhanced sockeye salmon into the wild stock sockeye salmon systems. We believe that the methods used to identify enhanced fish were relevant and accurate in separating the enhanced fish from the wild stocks. The enhanced fish were easily identifiable in the THA catch samples and would be as obvious within the wild stock escapement samples.

It has been postulated that sockeye salmon will attempt to find another stream when they encounter impassable barriers. However, due to the nature of the terminal harvest fishery, the large majority of the sockeye salmon are captured before they reach the barrier weir. The straying rate appears to be insignificant, perhaps there is an effective fishery in place at the terminal harvest areas. However, in the event of a fisheries strike or other unforeseeable disasters an effective fishery would no longer be possible. Therefore, it is the departments policy to dismantle the barrier and allow fish to pass upstream if such an event occurs.

It is our conclusion that the enhanced sockeye salmon stock returning to Hidden Creek does not have a significant group of fish straying to the Thorsheim Creek system, in part due to the effectiveness of the fishery.

The stock identification portion of the straying assessment at Portage Creek did not reveal any straying fish; however, there was some evidence of overlap with the fresh water circuli count and the fresh water annulus measurements between the WBTHA and Portage Creek scale samples taken in 1999. This overlap, in and of itself, does not indicate straying; many distinct populations can have such overlap. On the other hand, it might indicate a need for further examination. Again, the effectiveness of the fishery is key in the assumption of insignificant straying. The terminal harvest of the salmon at the WBTHA is an effective fishery. We believe that although there might be some possibility for straying at the Portage systems, there is still strong evidence that such straying, if any, is insignificant (less than 2%).

RECOMMENDATIONS

It is our recommendation that the barriers be installed in Hidden Lake Creek and Little Waterfall Creek again in 2000. We also recommend that a weir be placed at Portage Creek in order to conduct a more thorough sampling regime and obtain an additional two years of data for reassessing straying incidence.

LITERATURE CITED

ADF&G (Alaska Department of Fish and Game). 1998. Salmon Research Operational Plans for the Kodiak, Chignik and Aleutian Islands management areas, 1998. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 4K98-44, Kodiak.

ADF&G (Alaska Department of Fish and Game). 1999. Salmon Research Operational Plans for the Kodiak, Chignik and Aleutian Islands management areas, 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 4K99-44, Kodiak.

Barrett, B. M., C. O. Swanton, and P. A. Roche. 1990. An estimate of the 1989 Kodiak management area salmon catch, escapement, and run number had there been a normal fishery without the *Exxon Valdez* Oil Spill. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 4k90-35, Kodiak.

Borenstein, M., H. Rothstein and J. Cohen. 1997. SamplePower 1.0. SPSS Inc., Chicago, IL p. 217.

Clutter, R and L. Whitesel. 1956. Collection and Interpretation of sockeye salmon scales. International Pacific Salmon Fisheries Commission, Bulletin 9, New Westminster, British Columbia, Canada.

Edmundson, J. A., S. G. Honnold and G. B. Kyle, 1994. Trophic responses to juvenile sockeye salmon stocking and nutrient enrichment in barren Little Waterfall Lake. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 5J94-13, Kodiak.

Grant, W. S. (editor). 1997. Genetic effects of straying of non-native hatchery fish into natural populations: proceedings of the workshop. U.S. Dep. Commer., NOAA Tech Memo. NMFS-NWFSC-30, 130p.

Honnold, S. G., C. Clevenger and J. N. McCullough. 1998. Pillar Creek Hatchery annual management plan, 1998. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report No. 4K98-24 Kodiak.

Honnold, S. G., C. Clevenger, J. N. McCullough and S. T. Schrof. 1999. Pillar Creek Hatchery annual management plan, 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report No. 4K99-45, Kodiak.

INPFC (International North Pacific Fisheries Commission). 1963. Annual Report 1961. Vancouver, British Columbia, Canada

LITERATURE CITED (Cont.)

Johnson, R. A. and D. W. Wichern 1998. Applied Multivariate Statistical Analysis. Fourth Edition. Prentice Hall, NJ.

Koo, T.S.Y. 1962. Studies of Alaska red salmon. University of Washington, Publications in Fisheries, New series, Volume I. Seattle.

McGee, S. 1995. The Hatchery Program and Protection of Wild Salmon in Alaska: Policies and Regulations. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Juneau.

Mooney, C. Z. 1997. Monte Carlo Simulation. Sage University Paper series on Quantitative Applications in the Social Sciences, 07-116. Thousand Oaks, CA: Sage.

Nelson, P. 1999. An estimate of Spiridon Lake sockeye salmon commercially harvested within the Southwest Afognak Section and Northwest Kodiak District, 1997. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 4K99-25, Kodiak.

Nelson, P. and Barrett B. M. 1994. An estimate of Spiridon Lake sockeye salmon commercially harvested within the Southwest Afognak Section and Northwest Kodiak District, 1994. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 4K94-43, Kodiak.

Unwin, M. J. and G. J. Glova 1997. Changes in life history parameters in a naturally spawning population of chinook salmon (Oncorhynchus tshawytscha) associated with releases of hatchery-reared fish. Can. J. Fish. Aquat. Sci 54: 1235-1245.

White, L. E. 1992. Limnological and fisheries assessment of the potential production of sockeye salmon (*Oncorhynchus nerka*) in Hidden Lake. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement, and Development. Cooperative Agreement Number 90-013.

Quinn, T.P. 1993. A review of homing and straying of wild and hatchery-produced salmon. Fish. Res.18:29-44.

Table 1. Age composition summary table for FBTHA, WBTHA, Portage Lake, and Thorsheim Lake sockeye salmon, 1998.

Area		Ages											Totals
		1.1	1.2	1.3	2.1	1.4	2.2	2.3	2.4	3.1	3.2	3.3	
Foul Bay	Numbers	1	535	28	0	0	36	3	0	0	0	0	603
THA Catch	Percent	0	89	5	0	0	6	0	0	0	0	0	
Waterfall Bay	Numbers	2	264	65	0	0	5	1	0	0	0	0	337
THA Catch	Percent	1	78	19	0	0	1	0	0	0	0	0	
Portage Lake	Numbers	2	253	77	0	0	77	92	0	0	6	3	510
Escapement	Percent	0	50	15	0	0	15	18	0	0	1	1	
Thorsheim Lake	Numbers	2	114	9	1	2	22	267	1	0	1	0	419
Escapement	Percent	0	27	2	0	0	5	64	0	0	0	0	

Table 2. Age composition summary table for FBTHA, WBTHA, Portage Lake, and Thorsheim Lake sockeye salmon, 1999.

Area		Ages 0.2	0.3	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.2	Totals
Foul Bay	Numbers	0	0	161	331	94	0	23	33	4	0	646
THA Catch	Percent	0	0	25	51	15	0	4	5	1	0	
Waterfall Bay	Numbers	1	9	29	272	154	0	5	7	13	1	491
THA Catch	Percent	0	2	6	55	31	0	1	1	3	0	
Portage Lake	Numbers	0	0	37	19	45	1	92	83	5	1	283
Escapement	Percent	0	0	13	7	16	0	33	29	2	0	
Thorsheim Lake	Numbers	0	0	16	19	190	0	0	226	68	0	519
Escapement	Percent	0	0	3	4	37	0	0	44	13	0	

Table 3. Estimated total population and simulated sample sizes used for the Monte Carlo simulation.

Year	System	Date(s) used for the estimate of the total population.	Total Population (N)	Simulated sample size (n)
1998	Thorsheim Lake	May 31 - June 27	1,243	519
1998	Portage Lake	August 24 foot survey	3,948	283
1999	Thorsheim Lake	May 31 - July 4	5,978	419
1999	Portage Lake	August 24 foot survey	5,902	510

Table 4. Thorsheim Creek weekly and cumulative sockeye salmon weir counts, 1998-1999.

	Thorsheim			
	1998		1999	
Week	Weekly Count	Cumulative	Weekly Count	Cumulative
31-May to 06-Jun	157	157	0	0
07-Jun to 13-Jun	149	306	525	525
14-Jun to 20-Jun	776	1,082	515	1,040
21-Jun to 27-Jun	161	1,243	1,397	2,437
28-Jun to 04 Jul	5005 [a]	6,248	3541[b]	5,978
05-Jul to 11-Jul	0	6,248	0	5,978
12-Jul to 18-Jul	0	6,248	0	5,978
19-Jul to 25-Jul	0	6,248	0	5,978
26-Jul to 01-Aug	0	6,248	0	5,978
02-Aug to 08-Aug	0	6,248	0	5,978
09-Aug to 15-Aug	0	6,248	0	5,978
16-Aug to 22-Aug	0	6,248	0	5,978
23-Aug to 29-Aug	0	6,248	0	5,978
30-Aug to 05 Sep	0	6,248	0	5,978
06-Sep to 12-Sep	0	6,248	0	5,978
Totals:		6,248		5,978

[a] Includes a post-weir estimation of 5,000 fish in the bay.

[b] Includes a post-weir estimation of 1,000 fish in the bay.

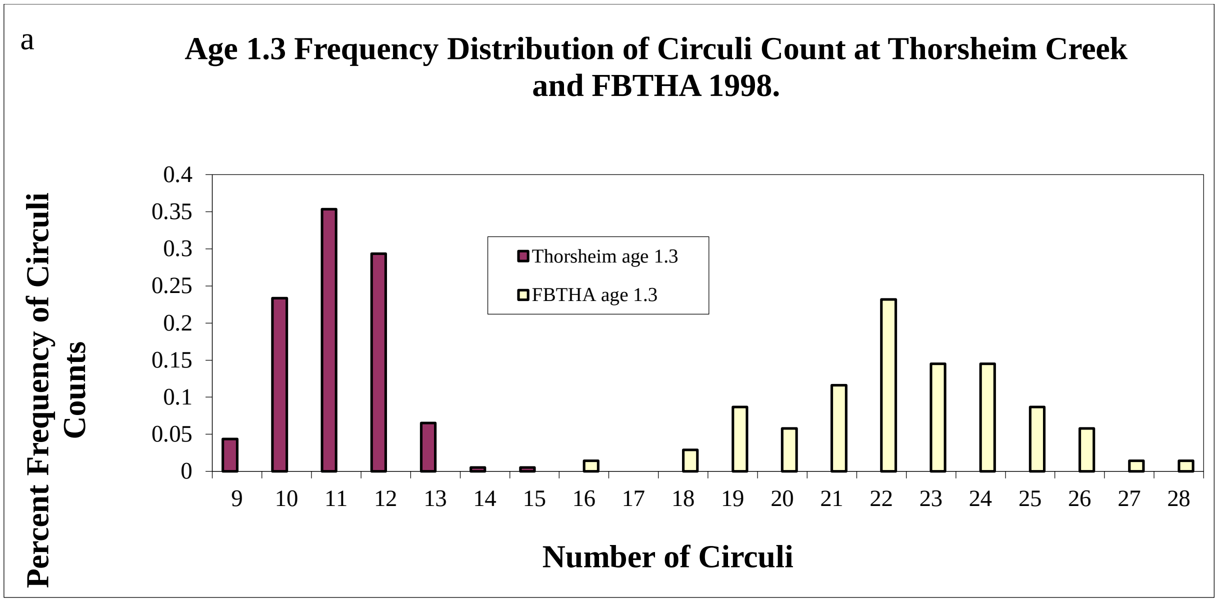
Table 5. Portage Lake tributary peak sockeye salmon counts and expanded escapement estimates, 1998-1999.

	1998		1999	
Date	Actual Live Counts	Estimated Escapement[a]	Actual Live Counts	Estimated Escapement[a]
26-Aug	1,974	3,948	2,951	5,902
Totals:		3,948		5,902

[a] The estimated escapement equals the actual live count multiplied by two (Barrett et al 1990).

Table 6. Foul Bay and Waterfall Bay Terminal Harvest Areas daily and cumulative sockeye salmon catch, 1998-1999.

	Foul Bay				Waterfall Bay			
	1998		1999		1998		1999	
Date	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative
9-Jun	567	567	3,720	3,720	3186	3,186	4,477	4,477
10-Jun	1,770	2,337	5,617	9,337	676	3,862	0	4,477
11-Jun	1,431	3,768	0	9,337	28	3,890	1,256	5,733
12-Jun	958	4,726	2,612	11,949	320	4,210	0	5,733
13-Jun	425	5,151	1,825	13,774	869	5,079	0	5,733
14-Jun	0	5,151	0	13,774	0	5,079	0	5,733
15-Jun	661	5,812	0	13,774	0	5,079	0	5,733
16-Jun	0	5,812	0	13,774	0	5,079	612	6,345
17-Jun	362	6,174	0	13,774	1991	7,070	0	6,345
18-Jun	682	6,856	1,500	15,274	0	7,070	0	6,345
19-Jun	235	7,091	0	15,274	907	7,977	0	6,345
20-Jun	0	7,091	0	15,274	0	7,977	0	6,345
21-Jun	712	7,803	1,368	16,642	712	8,689	1,046	7,391
22-Jun	0	7,803	1,751	18,393	900	9,589	0	7,391
23-Jun	0	7,803	1,356	19,749	0	9,589	0	7,391
24-Jun	0	7,803	2,315	22,064	418	10,007	0	7,391
25-Jun	0	7,803	1,031	23,095	240	10,247	763	8,154
26-Jun	0	7,803	768	23,863	0	10,247	0	8,154
27-Jun	421	8,224	561	24,424	610	10,857	605	8,759
28-Jun	0	8,224	211	24,635	0	10,857	180	8,939
29-Jun	0	8,224	1,246	25,881	0	10,857	0	8,939
30-Jun	46	8,270	874	26,755	200	11,057	0	8,939
1-Jul	0	8,270	0	26,755	0	11,057	0	8,939
2-Jul	0	8,270	237	26,992	0	11,057	0	8,939
3-Jul	0	8,270	0	26,992	0	11,057	0	8,939
4-Jul	0	8,270	0	26,992	0	11,057	0	8,939
5-Jul	0	8,270	0	26,992	0	11,057	414	9,353
6-Jul	0	8,270	0	26,992	0	11,057	0	9,353
7-Jul	0	8,270	310	27,302	0	11,057	0	9,353
16-Aug	0	8,270	0	27,302	0	11,057	6	9,359
Totals:		8,270		27,302		11,057		9,359



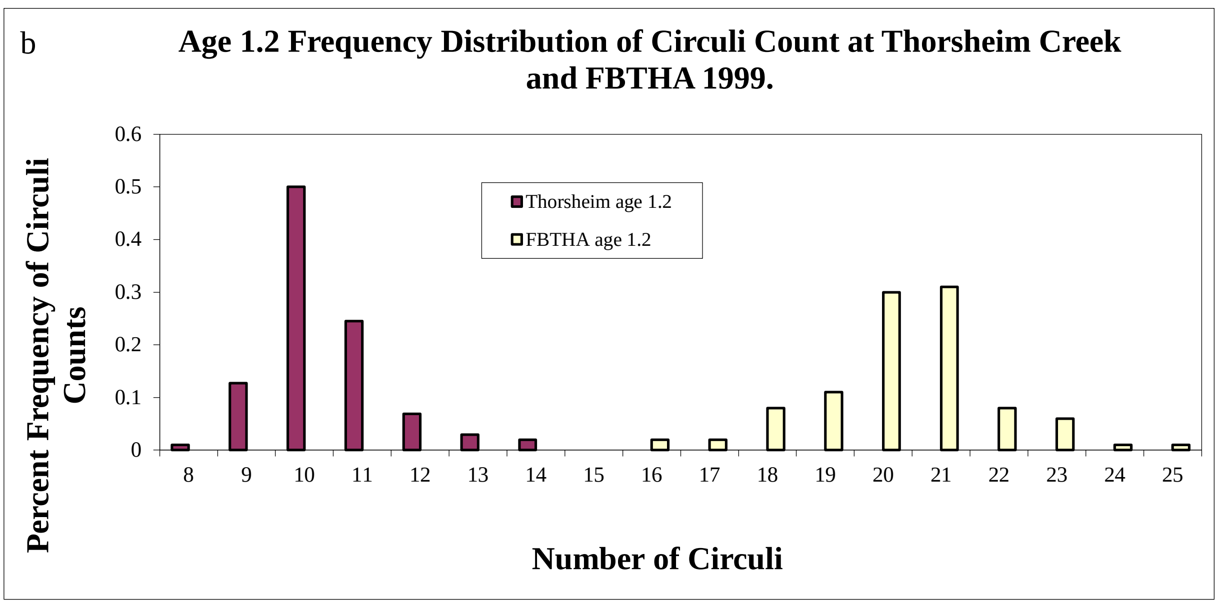
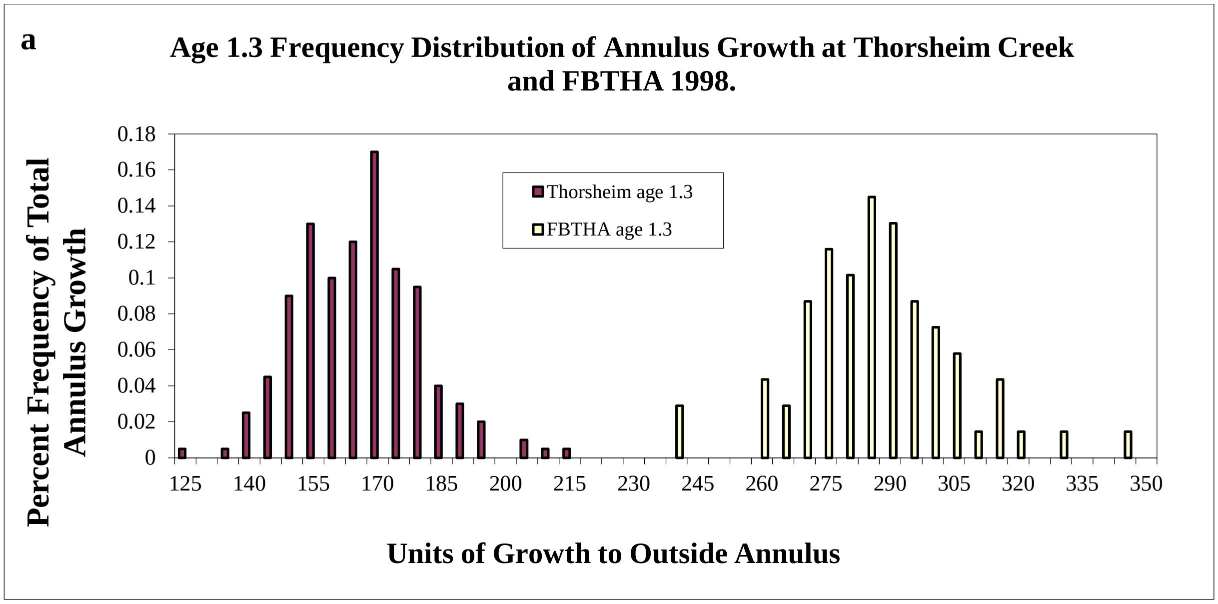


Figure 2. Frequency distribution of circuli counts for age 1.3 and age 1.2 sockeye salmon at Thorsheim Creek and the FBTHA, 1998 (a) and 1999 (b), respectively.



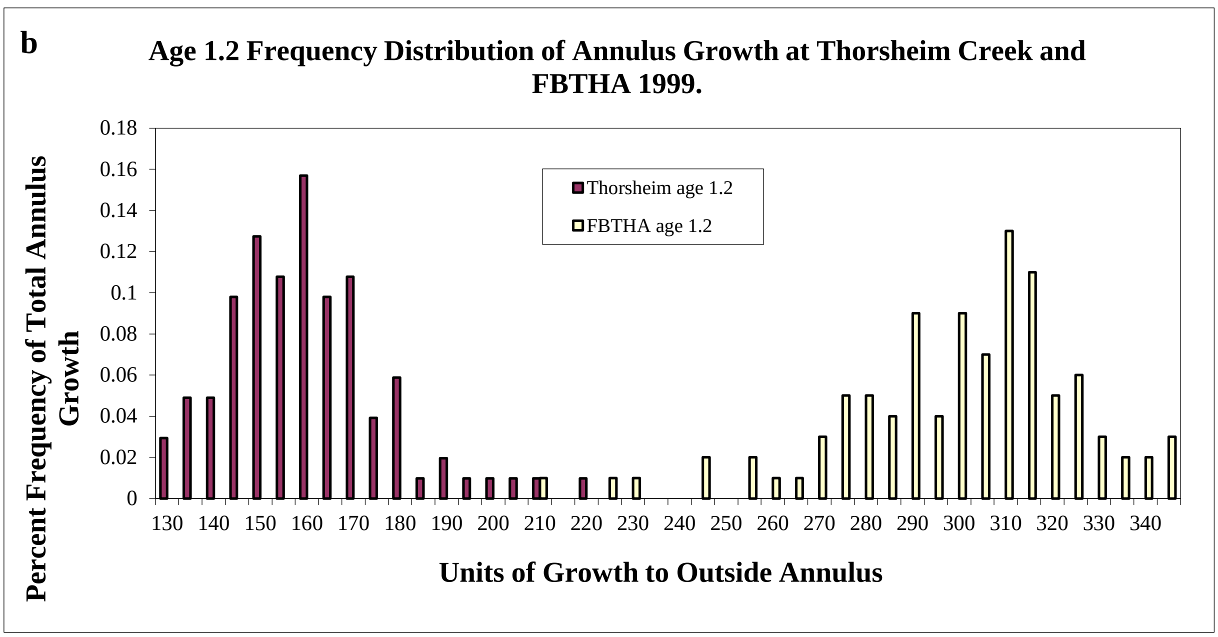


Figure 3. Frequency distribution of annulus growth for age 1.3 and age 1.2 sockeye salmon at Thorsheim Creek and the FBTHA, 1998 (a) and 1999 (b), respectively.

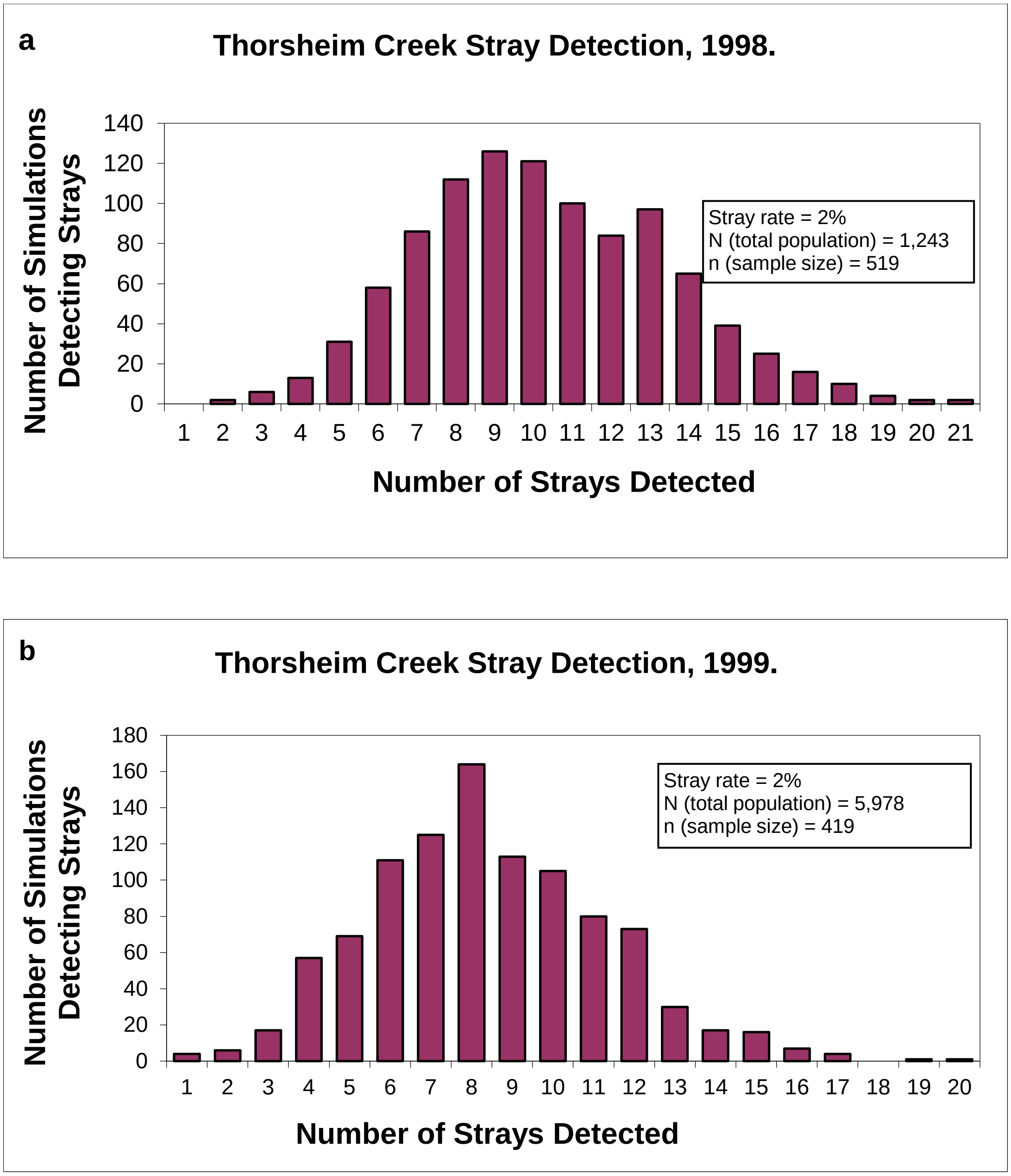
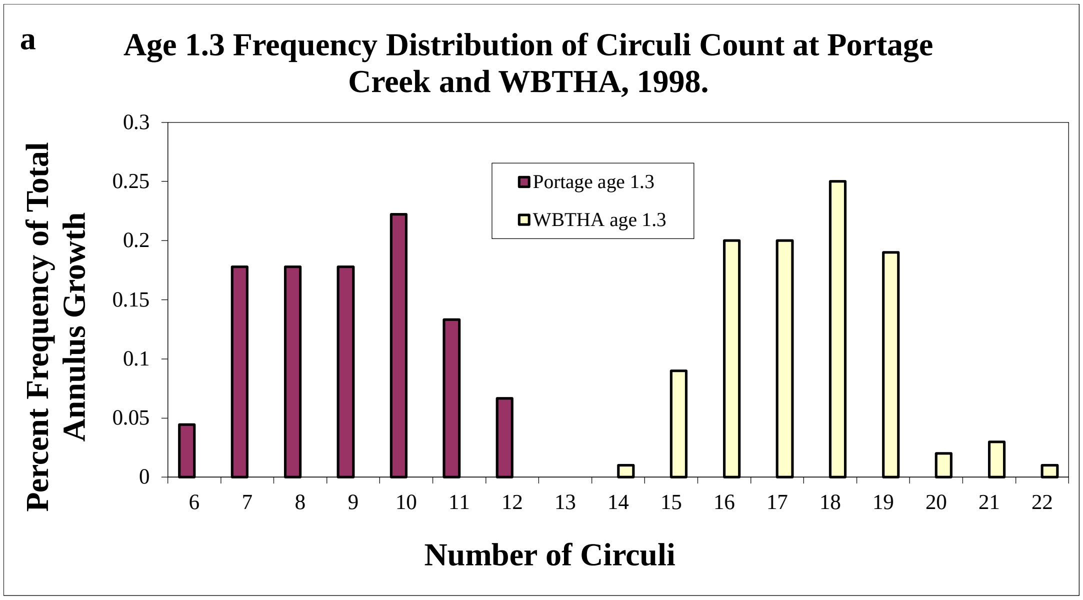


Figure 4. Simulated stray detection (2% straying rate) of enhanced sockeye salmon into a natural sockeye salmon stock: (a) Thorsheim 1998, (b) Thorsheim 1999.



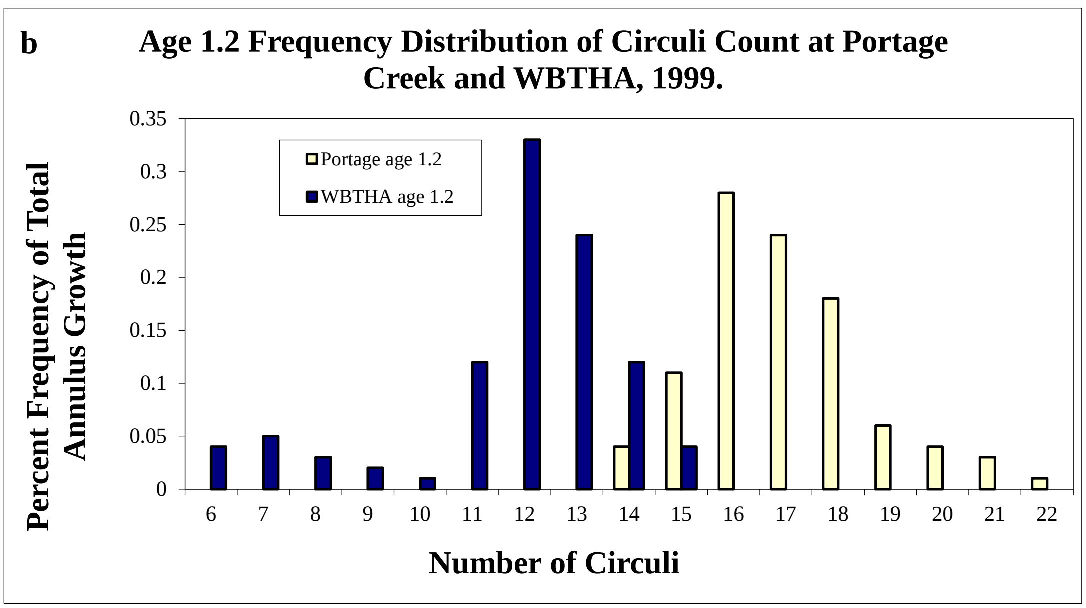
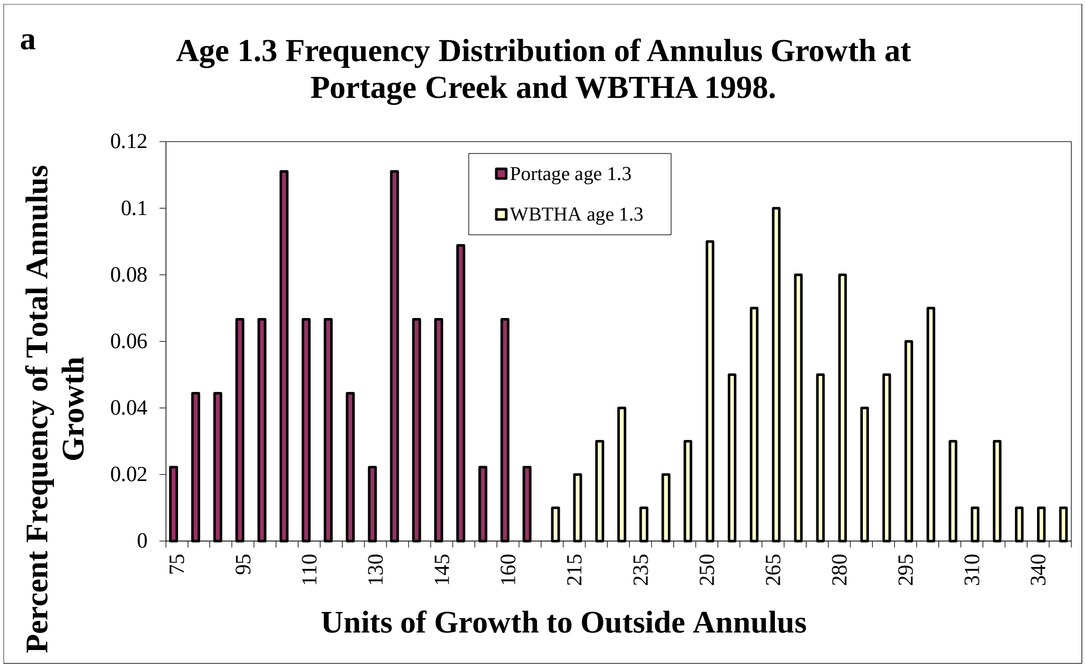


Figure 5. Frequency distribution of circuli counts for age 1.3 and age 1.2 sockeye salmon at Portage Creek and the WBTHA, 1998 (a) and 1999 (b), respect



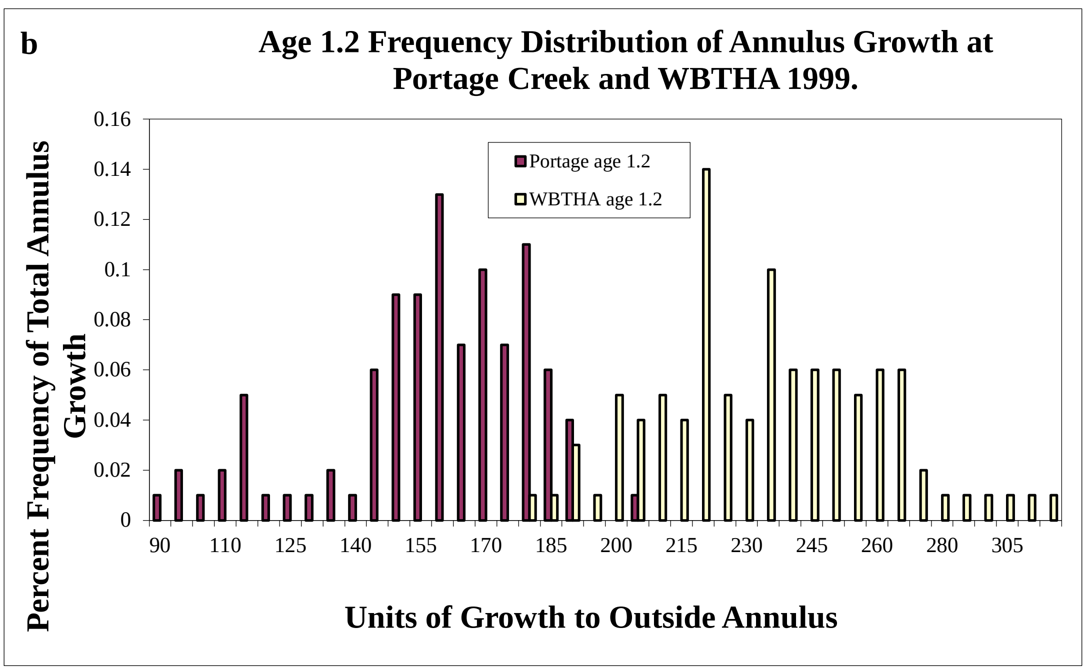
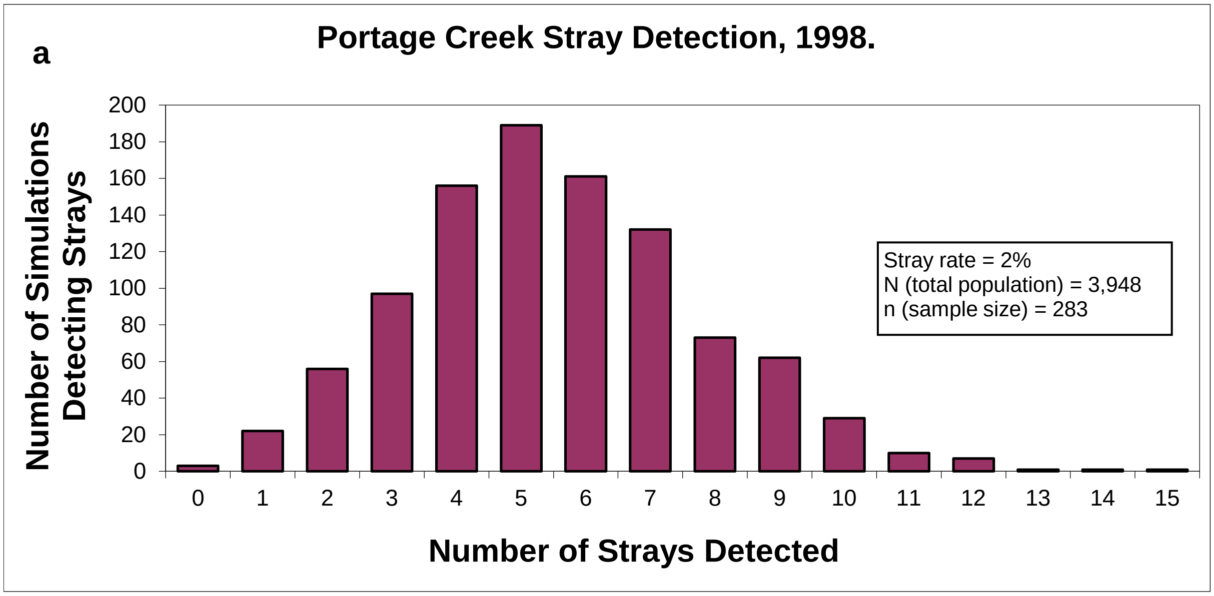


Figure 6. Frequency distribution of annulus growth for age 1.3 and age 1.2 sockeye salmon at Portage Creek and the WBTHA, 1998 (a) and 1999 (b), respect



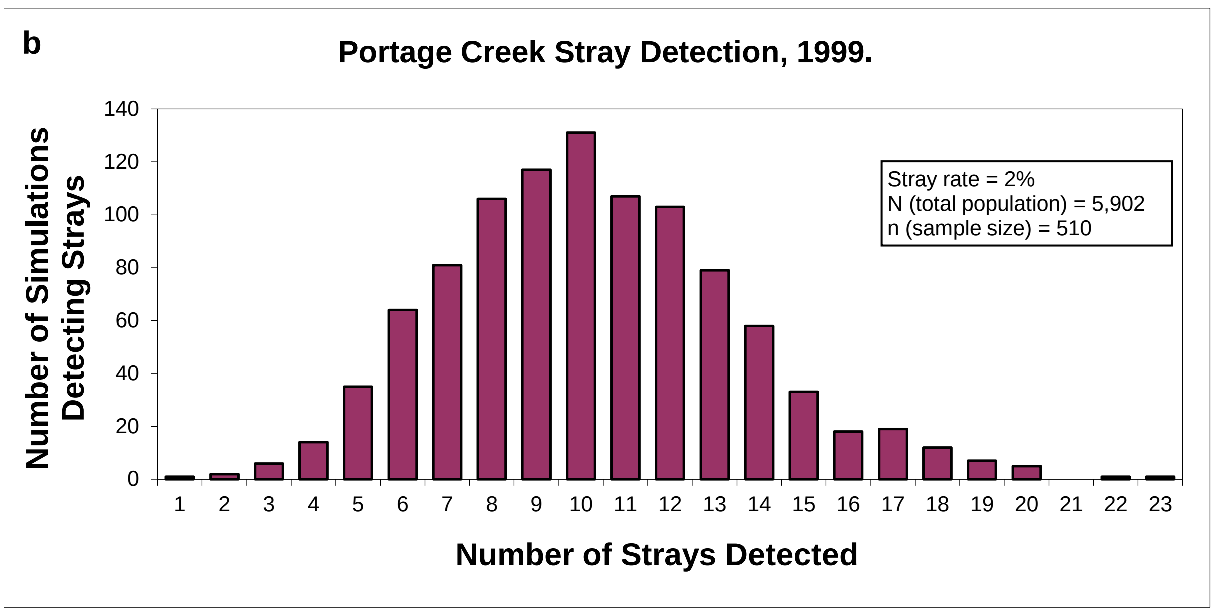
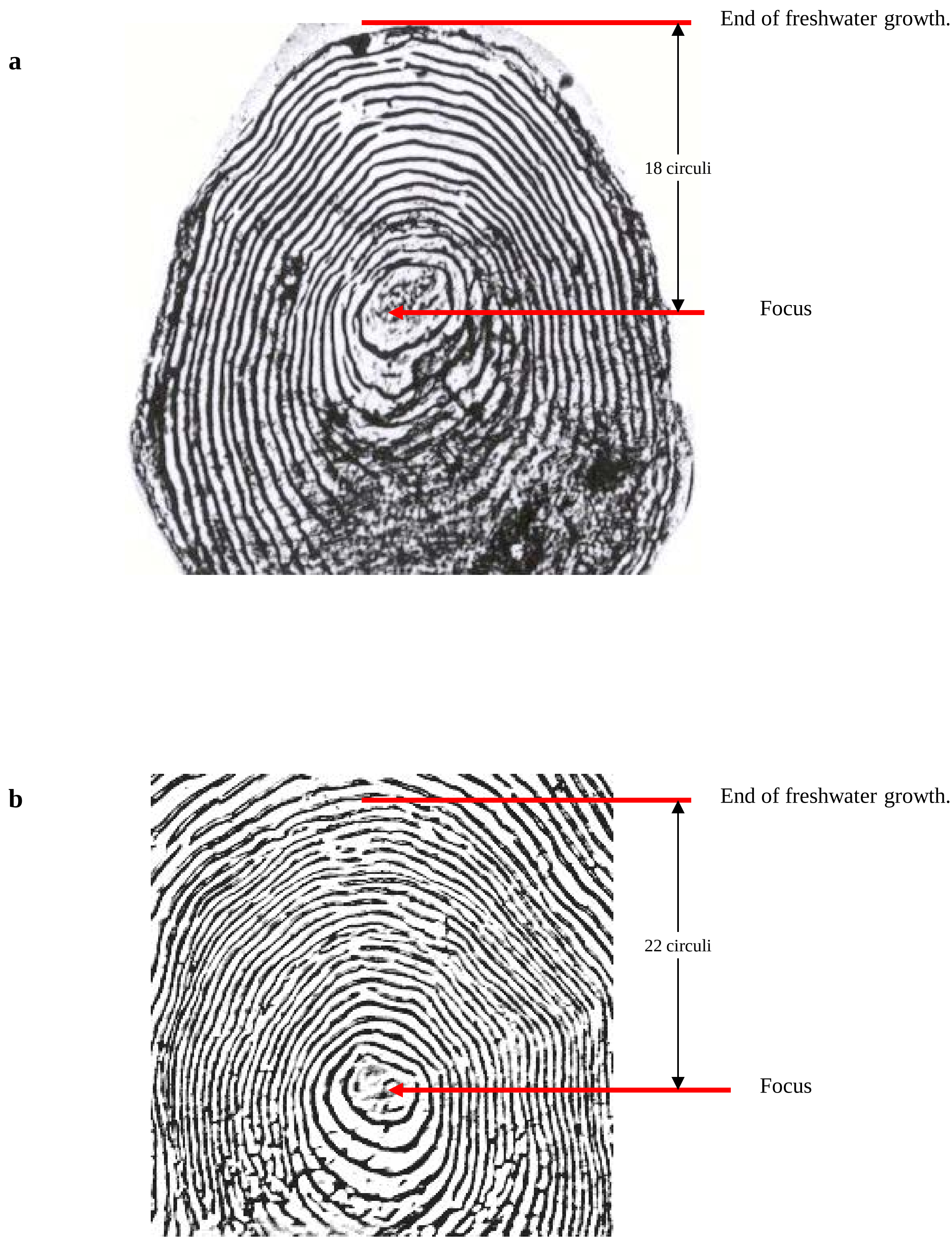
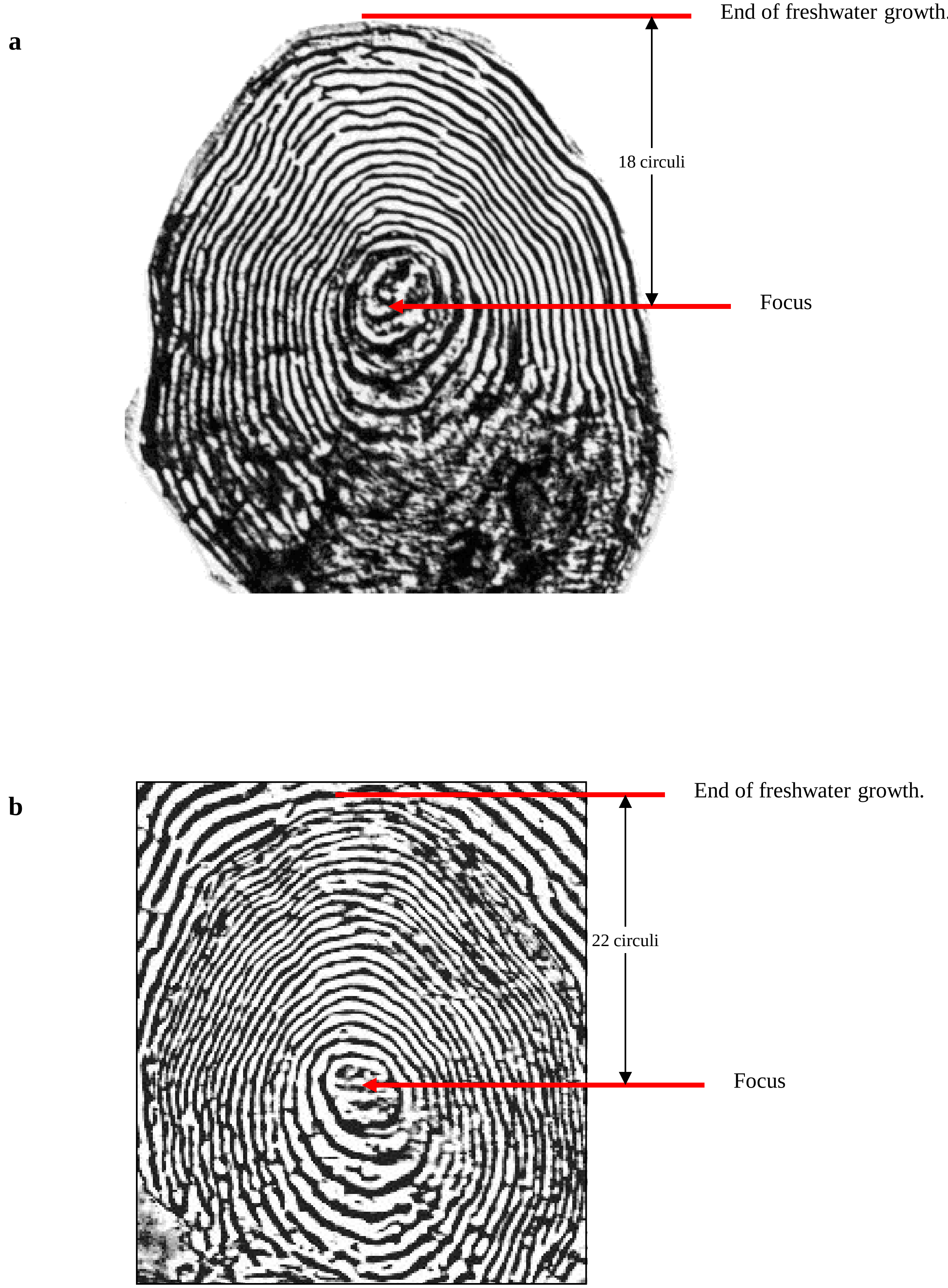


Figure 7. Simulated stray detection (2% straying rate) of enhanced sockeye salmon into a natural sockeye salmon stock: (a) Portage 1998, (b) Portage 1999.

APPENDIX

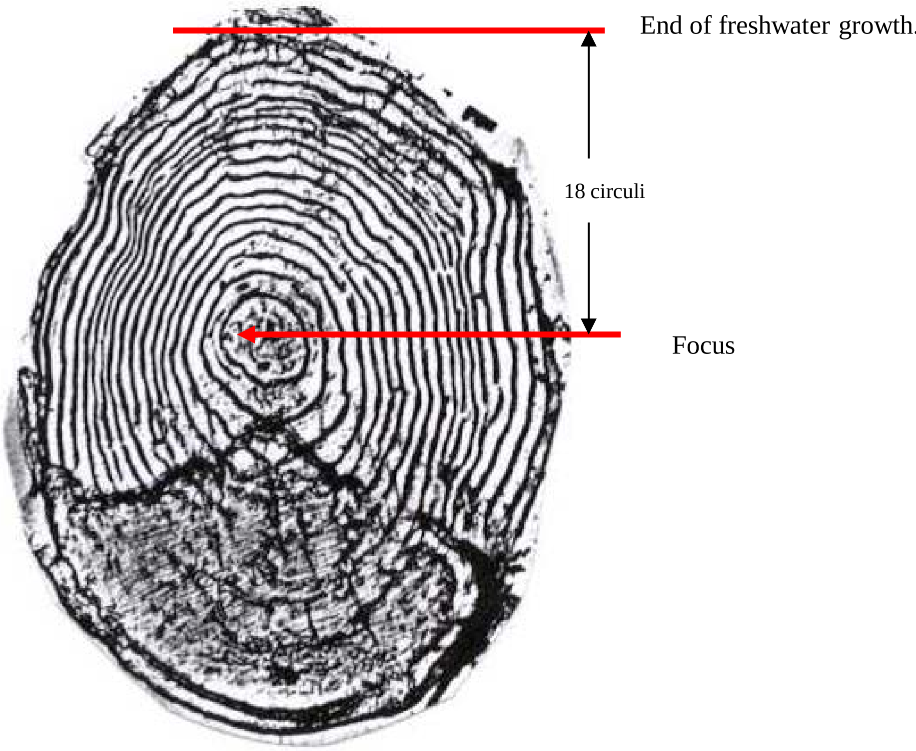


Appendix A.1. Comparison of 1994 pre-smolt (a) and 1999 age 1.3 FBTHA adult sockeye salmon (b).

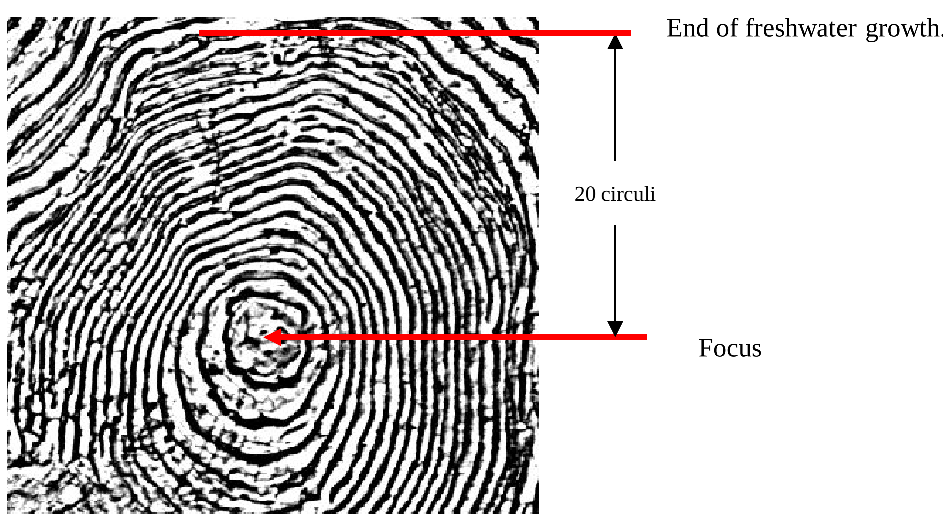


Appendix A.2. Comparison of 1996 pre-smolt (a) and 1998 age 1.2 FBTHA adult sockeye salmon (b).

a

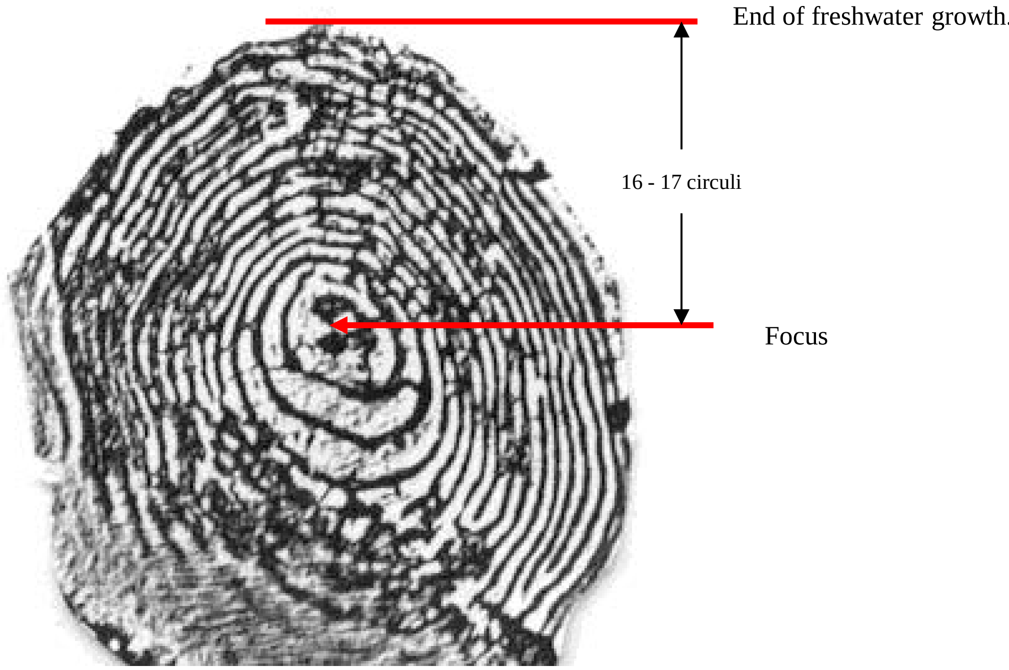


b

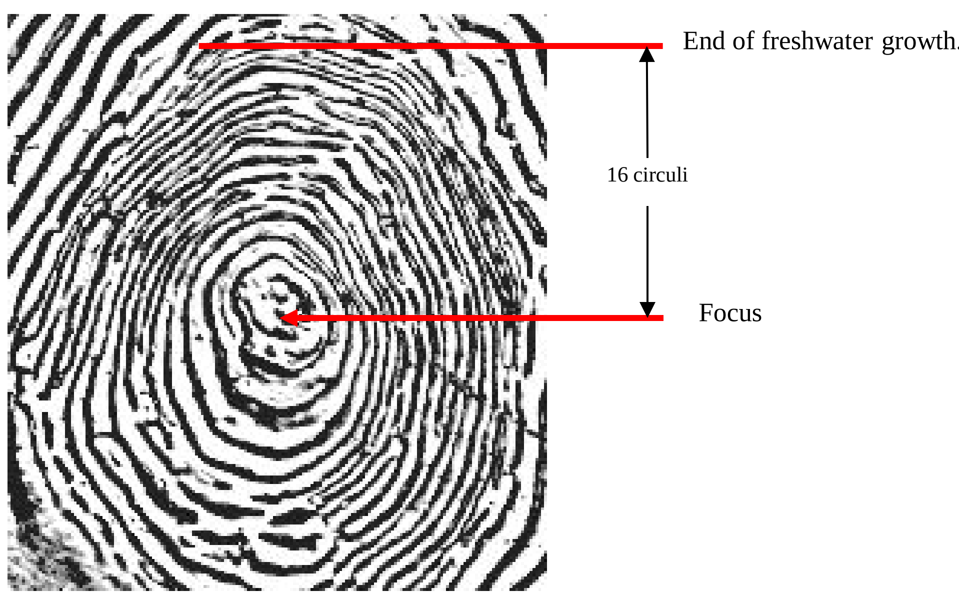


Appendix A.3. Comparison of 1994 pre-smolt (a) and age 1.3 1998 1.3 WBTHA adult sockeye salmon (b).

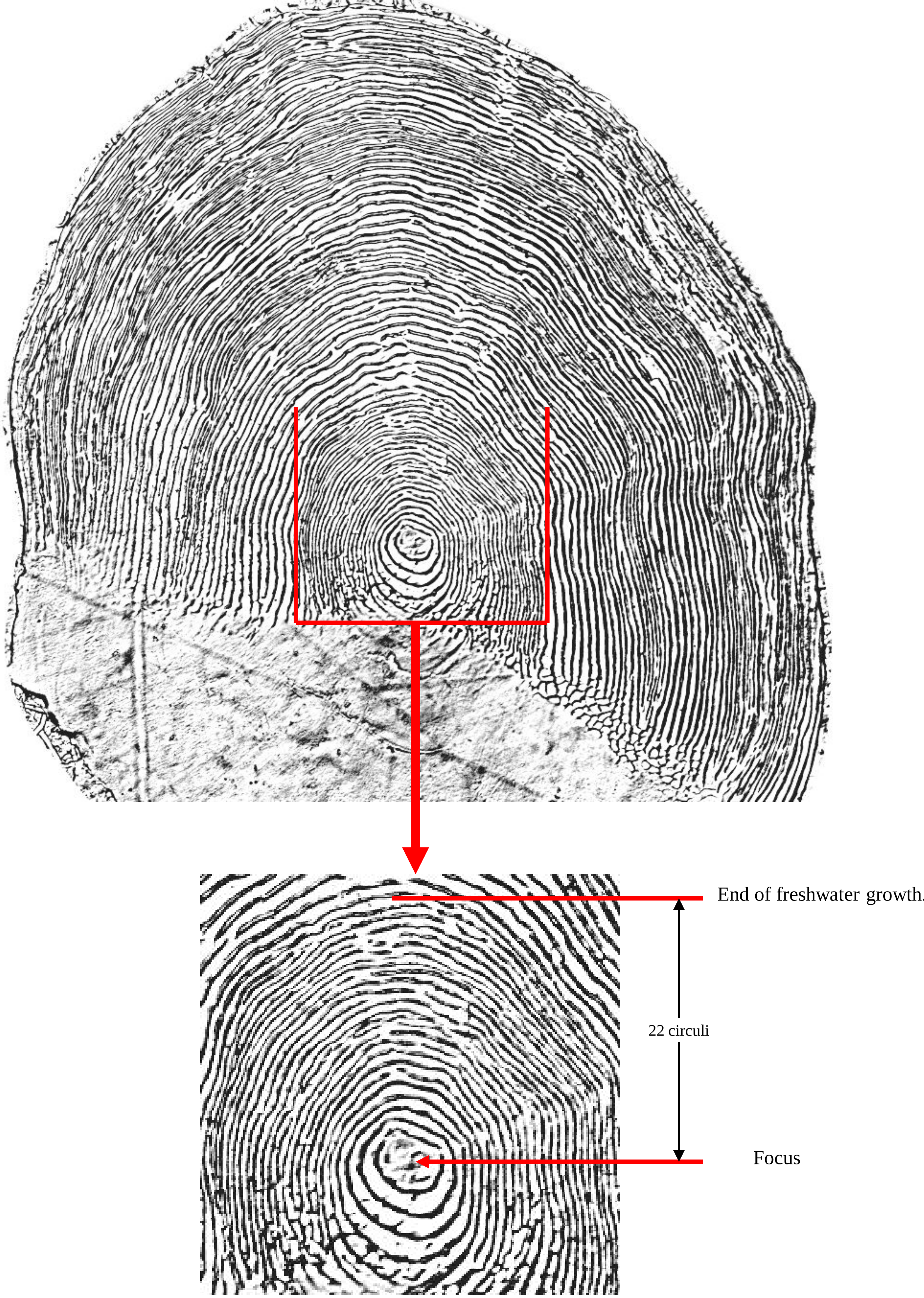
a



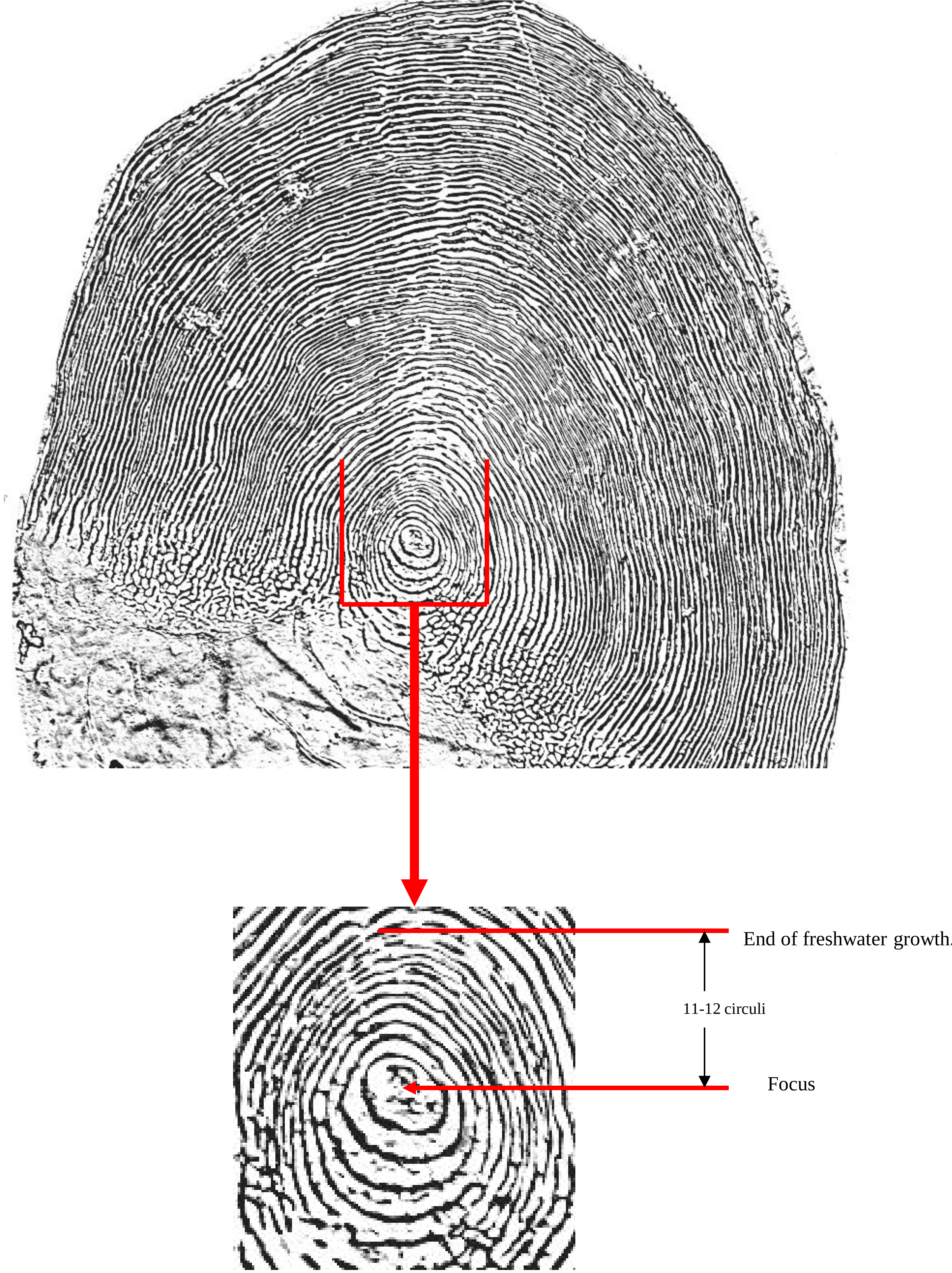
b



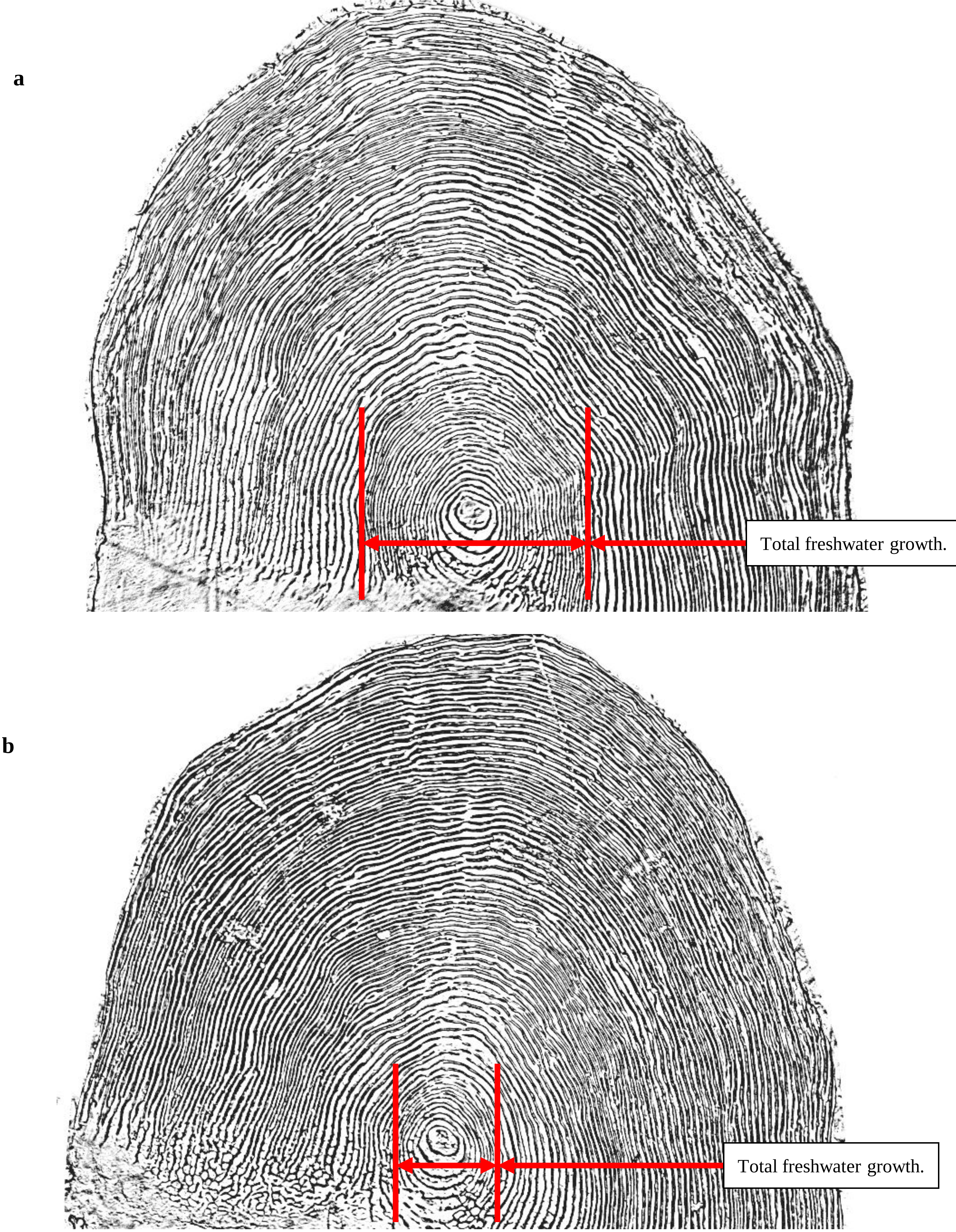
Appendix A.4. Comparison of 1996 pre-smolt (a) and 1999 age 1.2 WBTHA adult sockeye salmon (b).



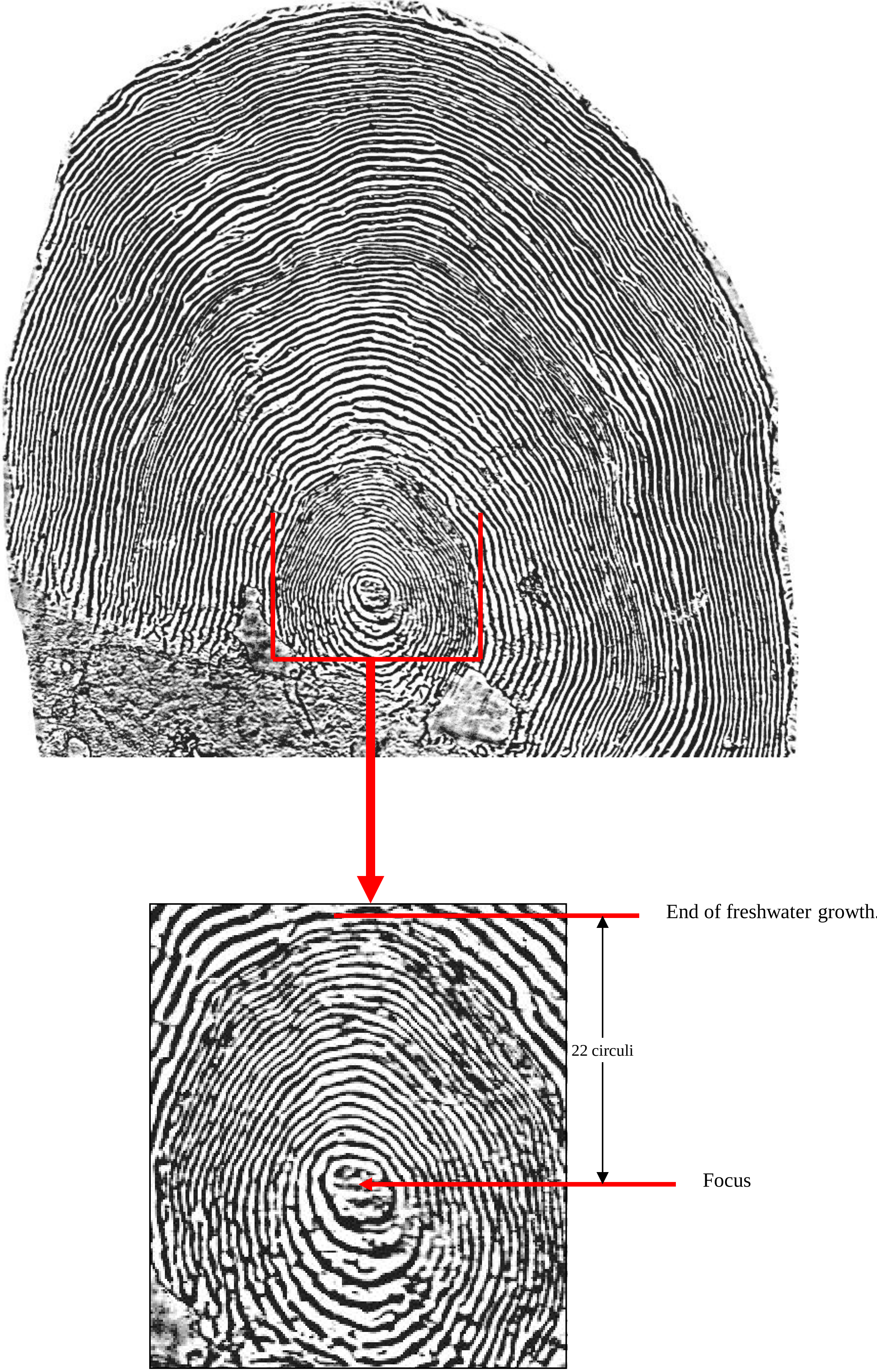
Appendix B.1. Scale pattern of age 1.3 sockeye salmon collected in the FBTHA fishery, 1998.



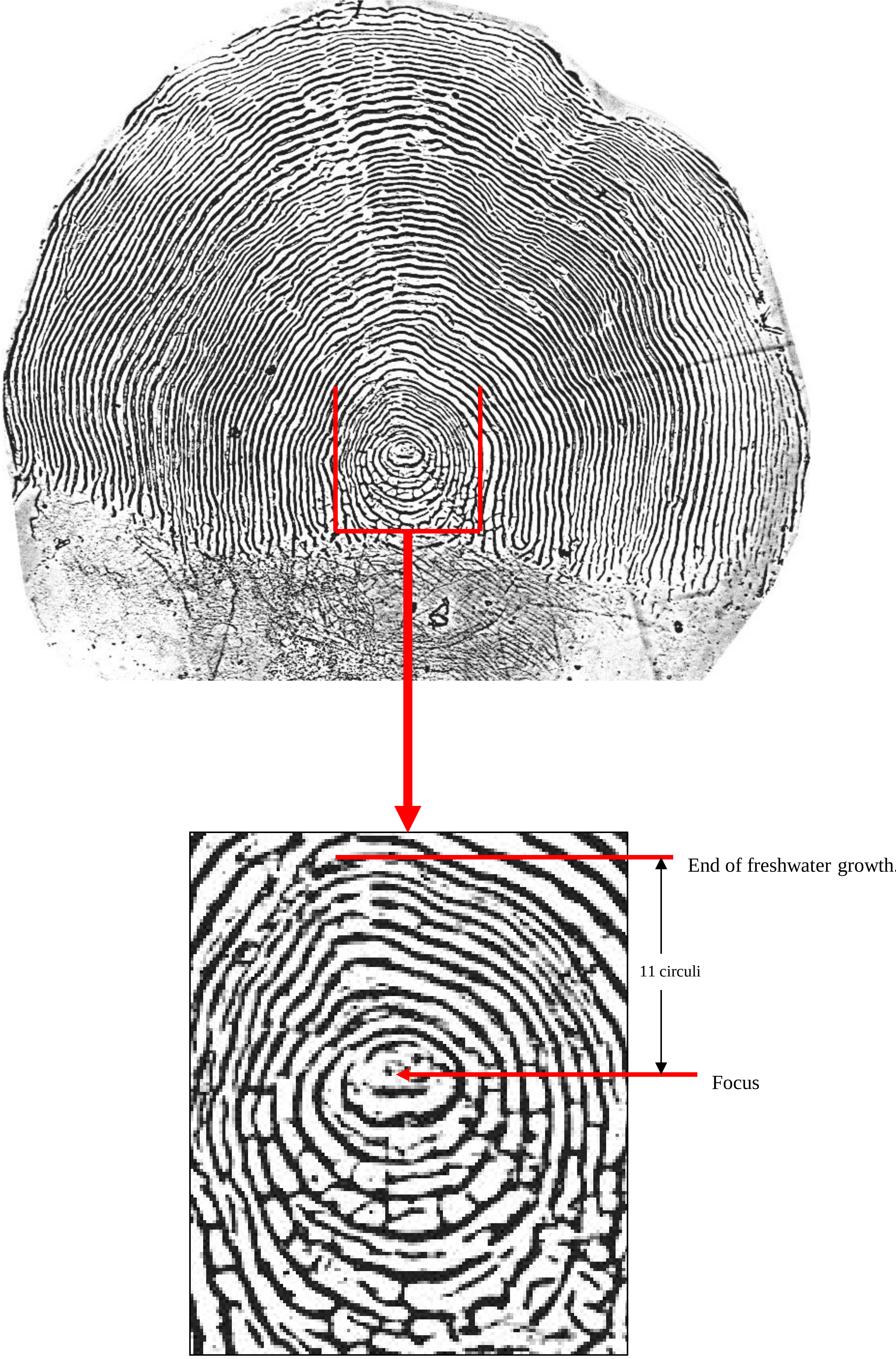
Appendix B.2. Scale pattern of age 1.3 sockeye salmon collected at Thorsheim Creek, 1998.



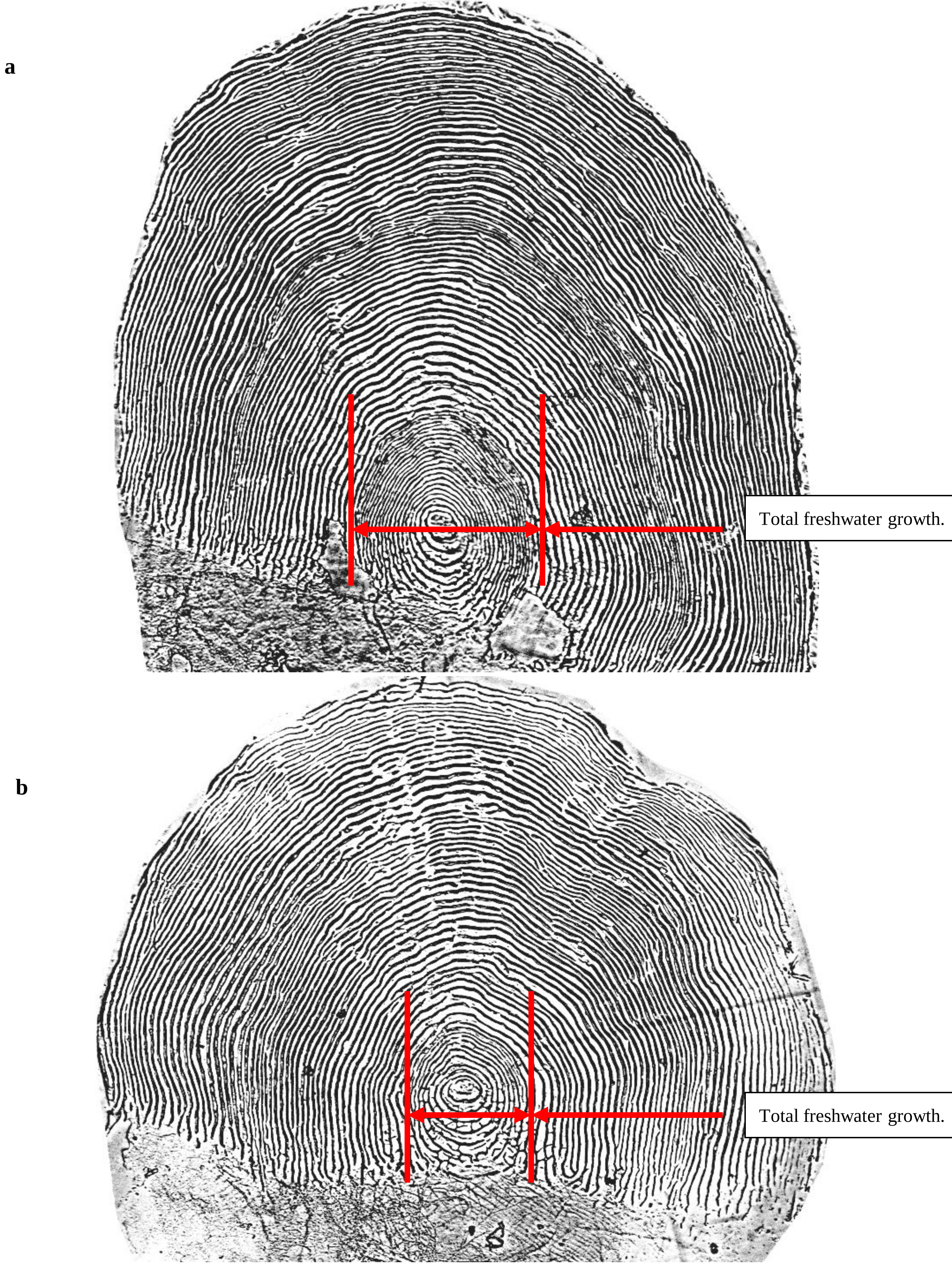
Appendix B.3. Comparison of age 1.3 FBTHA enhanced sockeye salmon (a) and Thorsheim Creek wild sockeye salmon (b), 1998.



Appendix B.4. Scale pattern of age 1.2 sockeye salmon collected in the FBTHA fishery, 1999.



Appendix B.5. Scale pattern of age 1.2 sockeye salmon collected at Thorsheim Creek 1999.

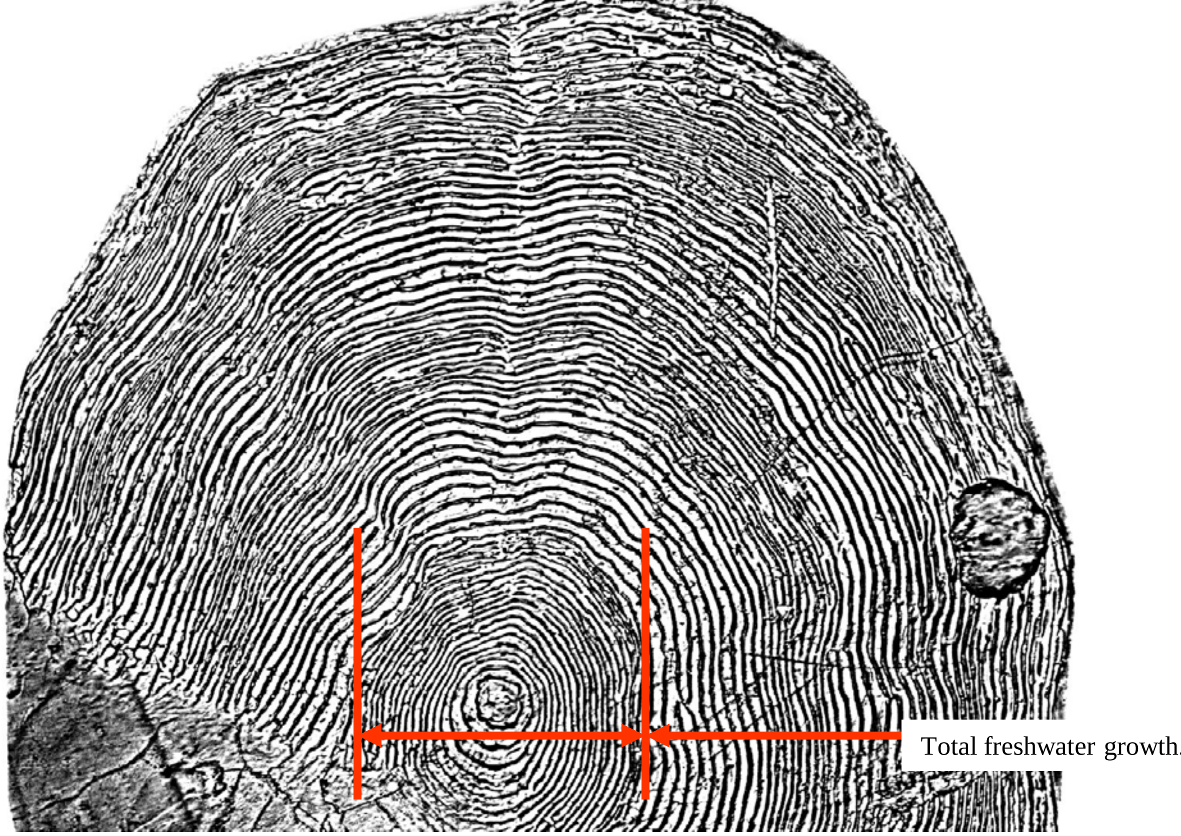


Appendix B.6. Comparison of age 1.2 FBTHA enhanced sockeye salmon (a) and Thorsheim Creek wild sockeye salmon (b) 1999.

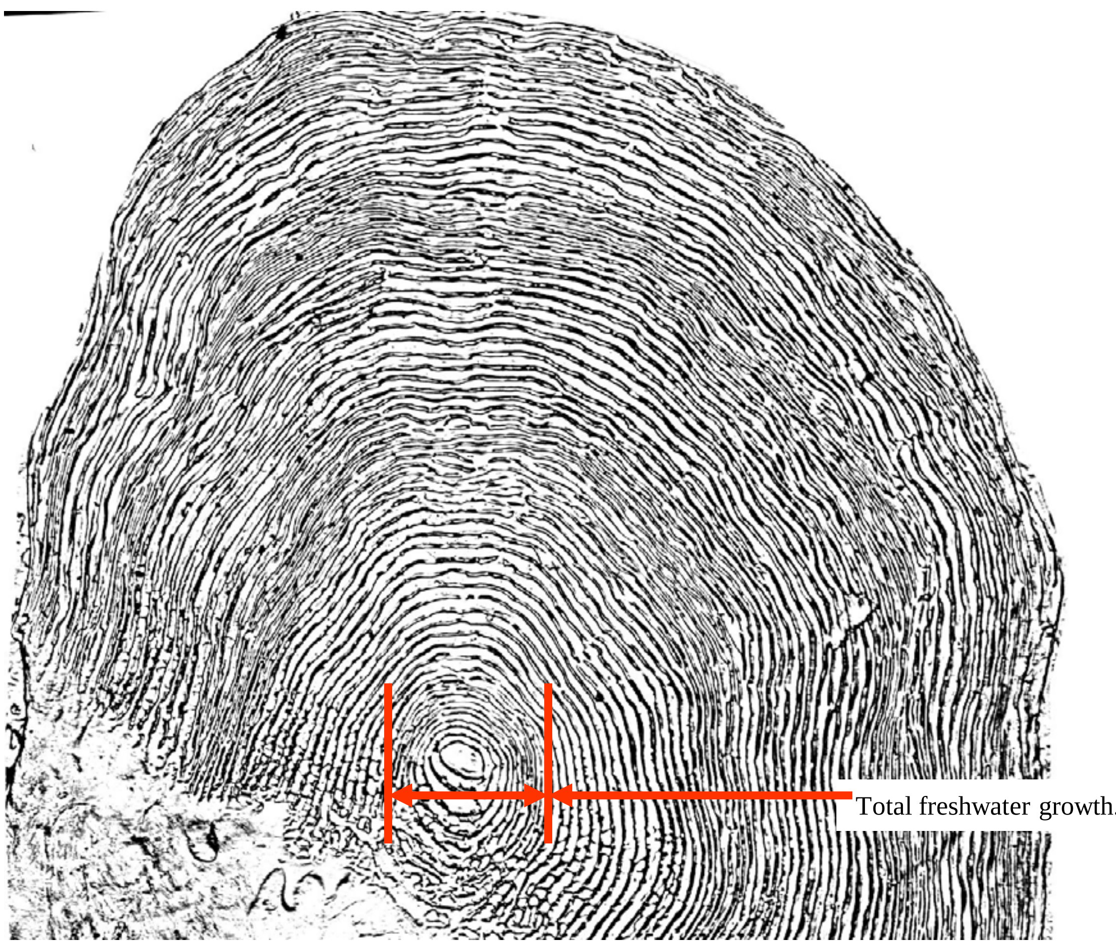
Appendix C.1. Scale pattern of age 1.3 sockeye salmon collected in the WBTHA fishery, 1998.

Appendix C.2. Scale pattern of age 1.3 sockeye salmon collected at Portage Creek, 1998.

a

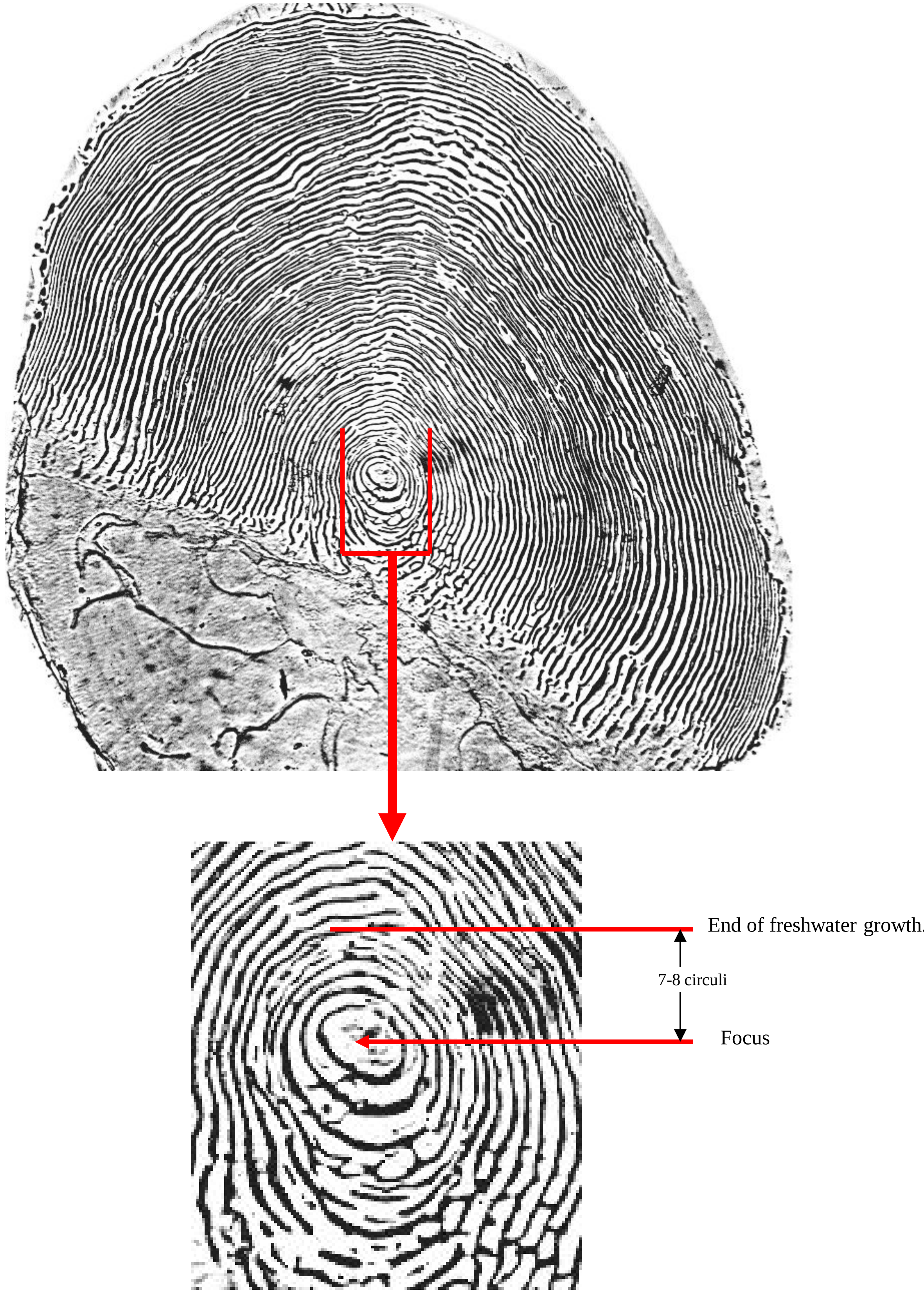


b

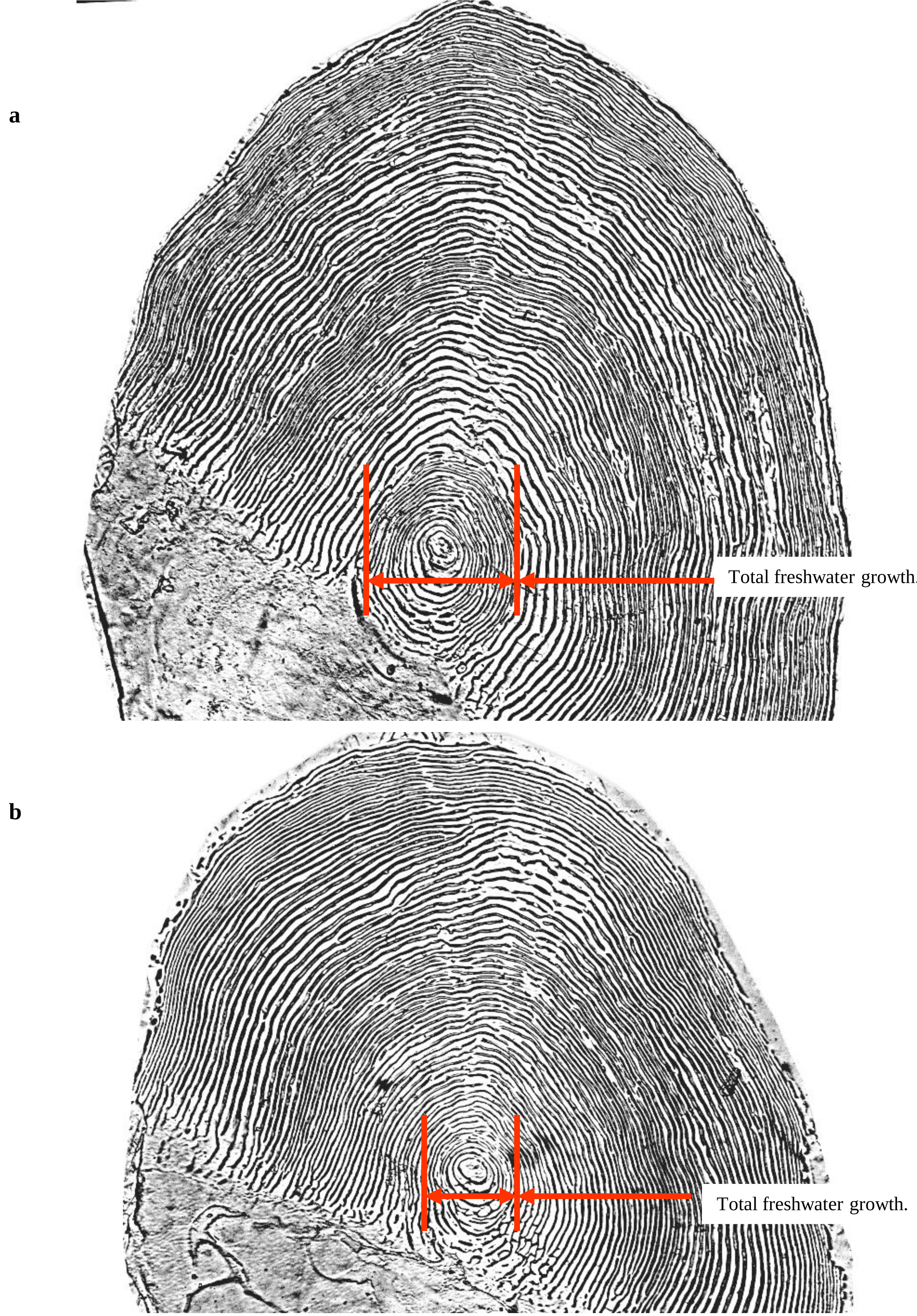


Appendix C.3. Comparison of age 1.3 WBTHA enhanced sockeye salmon (a) and Portage Creek wild sockeye salmon (b), 1998.

Appendix C.4. Scale pattern of age 1.2 sockeye salmon collected in the WBTHA fishery, 1999.



Appendix C.5. Scale pattern of age 1.2 sockeye salmon collected at Portage Creek, 1999.



Appendix C.6. Comparison of age 1.2 WBTHA enhanced sockeye salmon (a) and Portage Creek wild sockeye salmon (b), 1999.